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THE PSYCHOLOGICAL REVIEW

EXTRAEXPERIMENTAL SOURCES OF INTERFERENCE IN FORGETTING[1]

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This paper deals with sources of interference as related to the retention of serial verbal lists. More particularly, it is concerned with extraexperimental sources of interference. The presentation involves three steps: (*a*) the background facts and thinking which led to a conception of how extraexperimental sources of interference may influence retention; (*b*) the reporting of an experiment designed to evaluate certain implications of the conception; and (*c*) a reexamination of the conception in light of the experimental evidence.

BACKGROUND

We will start with the premise that interference is a major cause of forgetting. The facts of retroactive and proactive inhibition show that much forgetting can be produced by having subjects learn lists which, due to specifiable similarity, will interfere directly with the recall and relearning of another list. But we also know that forgetting of verbal lists will be produced by other lists not designed to be particularly similar, and that the amount of such forgetting is directly related to the number of lists learned prior to the learning of the list to be recalled (Underwood, 1957a). From such facts it would seem that a reasonable empirical extension could be made to cover forgetting where no formal interfering tasks are used. That is to say, it does not seem an overgeneralization to suggest that forgetting which occurs without the presence of a formal interfering task might be due to extraexperimental sources of interference. These interferences may arise as a consequence of new learning which occurs during the retention interval (thus simulating retroactive inhibition), or they may occur as a consequence of learning which had occurred prior to the learning of the task to be recalled (proactive inhibition). This latter case requires further discussion.

How can habits learned previously (a month, a year, or 10 years ago) interfere with the retention of a task being learned at the present time? Two assertions seem necessary to make this situation comprehensible. First, it must be assumed that the verbal habits being learned at the present

[1] We are grateful to Audrey Bohm and Polly Davis for their assistance in the conduct of the experiment reported in this paper.

time require the breaking, extinction, unlearning, or inhibition of previously acquired habits. Secondly, the evidence indicates (e.g., Briggs, 1954) that extinguished verbal habits show at least a relative recovery (i.e., relative to the associations of the task to be recalled) in strength with the passage of time, and that this recovery may occur without the performance of these habits. Of course, if Habit A is extinguished in learning Habit B, and then if A is practiced again before a retention test for B is given, the recovery of A would be facilitated and the interference with B should be maximal. However, as noted, it appears that at least a relative recovery of an extinguished verbal habit will occur when it is not practiced. By such mechanisms, forgetting due to sources of interference established prior to the learning of a task to be recalled can be accounted for.

It is apparent that if the above argument is allowed to remain as is, a clear gap is present. For, we assert that the evidence from the formal proactive and retroactive operations leads to an interference conception of forgetting which in turn leads to the assertion that when *no* formal interfering task is given the forgetting observed must be due to extraexperimental sources of interference. As plausible as this argument may seem, it is apparent that it would be highly desirable to specify possible sources of extraexperimental interference, and to specify these in such a way that experimental tests of their influence on forgetting are possible. We will suggest two such sources.

Letter-sequence Interference

One source of interference is believed to come from well-established letter-sequence habits. By well-established letter-sequence habits we simply mean habits that are developed through the normal course of learning the language. It may be thought of as producing intraunit interference or between-letter interference. As an extreme illustration, a low-association value consonant syllable such as JQB may be considered. If this syllable were in a list which the subject has to learn, it is assumed that: (*a*) Previously learned letter-sequence habits will make this particular sequence difficult to learn since the previously established habits will have to be extinguished. For example, Q never follows J in the language, but all the vowels do. These habits, we presume, must be extinguished or, inhibited before the syllable can be learned. (*b*) With the passage of time following learning of the syllable, these older habits will recover and interfere at the time of the retention test. In addition, it is quite likely that the previously established letter habits will be used during the retention interval to augment the interference resulting from recovery.

If letter-sequence habits produce interference, the magnitude of this interference will decrease as the letter sequences more and more approximate the most frequent sequences in the language. Thus, we may conceive of a gradient of interference which diminishes in amount as the letter sequences whose retention is being tested come more and more in correspondence with those most frequently used in the language. When the letter sequences make up a very frequently used word, or even a frequently used sequence not forming a word (e.g., SOM), we would predict little among-letter interference either during learning or at recall. In Mandler's (1954) terminology, such sequences are said to be well integrated. To state the supposed relationship using this term

it would be said that the greater the degree of integration of a verbal unit the less will that unit suffer from interference from previously established letter-sequence habits.

Unit-sequence Interference

The second potential source of interference will be referred to as unit-sequence interference. By the *unit* we mean a word or sequence of letters appearing in a list as an idependent unit. Each syllable in a list of nonsense syllables is a unit, as is each word in a list of words. The interference we are referring to, then, is the interference falling on sequential associations between units. Conceptually, it may be thought of intially in exactly the same way as the interference between letters within a unit. As an illustration, assume that the word *over* is a unit in a serial list. Assume further that, due to long existing language habits, there is a strong tendency for the *over* to elicit *there*. We presume that this association will have to be extinguished before a new association can be established, but that with the passage of time the original association will recover to interfere with retention. In addition, since the sequence *over-there* will probably occur (be said, or heard) during a retention interval, the recovery process of the interfering association will be augmented by its use.

While the above unit-sequence interference is believed to be reasonable, it would appear that a further source of such interference would occur if the units which have pre-experimental associations are in the list being learned. To continue the above example, if both *over* and *there* were units in a serial list, but were not in adjacent serial positions, the strong association between them should interfere with whatever associations are required by the order of the items.

Generally speaking, the more frequently a word occurs in the language, the greater is the number of words with which it is associatively connected. This fact can be obtained directly from the production method of scaling meaningfulness (e.g., Noble, 1952). This means that if high-frequency words are used in a serial list, there will be a large number of pre-experimental associations existing among the items, many of which will have to be extinguished in order for the subject to achieve the particular order of items required by the experimenter. It would be expected, therefore, that the recovery of these pre-experimental associations over a retention interval would result in considerable interference at the time of the retention test. Thus, the unit-sequence conception of interference allows the derivation of a second gradient of interference from extraexperimental sources, with maximum interference being present with high-frequency words, and decreasing as the frequency of use of the units in the language decreases. It should be noted parenthetically that this assumed source of interference may actually facilitate retention under certain conditions. For example, such interitem associations should facilitate retention if the subject is *not* required to learn the items in any particular order and is *not* required to recall them in any particular order (Deese, 1959).

The operation of the two gradients of interference may now be summarized. The letter-sequence interference gradient will be at a maximum when the pre-experimental associative strength between letters is low. The amount of such interference will decrease as the pre-experimental associative connection between letters increases. When

the associative connection between letters becomes of a strength found among letters in low-frequency words, another gradient, the unit-sequence gradient, begins to emerge. The amount of interference expected from this gradient continues to increase up to the point where very high-frequency words are present. Roughly speaking, this entire dimension, incorporating both gradients, can be thought of in terms of the classical dimension of meaningfulness. The letter-sequence interference gradient is maximal with low meaningfulness, the unit-sequence interference gradient maximal with high meaningfulness. Both decrease toward intermediate degrees of meaningfulness. The problem of the extent of the gradients, and the degree of overlap, we leave to a later section.

Do available data give support to the above conception? It should be noted that adequate tests of the hypothesis require careful selection of material. But, in addition, two procedural criteria must be adhered to. First, since the conception is concerned with extraexperimental interference, the subjects used must not have learned material in the laboratory which might interfere. Essentially, this means the use of subjects completely naive to verbal-learning experiments. The second criterion which must be met is that degree of learning before the retention interval must be properly assessed for the different materials. Differences in rate of learning might well be expected if materials of different difficulty (via meaningfulness) are involved. Since retention is a function of degree of original learning, and since rate of learning and strength at end of learning are related, whatever method is used must show that differences which occur in retention cannot be attributed to differences in degree of original learning.

Not many available studies meet the above requirements. But, even those that do, do not give much encouragement to the assumed operation of the two gradients. Two studies (Postman & Rau, 1957; Underwood & Richardson, 1956) indicate that within the range of meaningfulness of Glaze nonsense syllables, there is little difference in retention. Furthermore, in the Postman-Rau experiment, words (as scaled by Noble, 1952) differed only little from nonsense syllables. In short, these studies would give no support to either of the proposed gradients. Yet, for a number of reasons, these studies may not be appropriate tests. Primarily, these reasons center around materials and length of retention interval. We believe that the plausibility of such interference gradients is high enough to warrant a specific test in which materials are chosen in a fashion to maximize the effects of the gradients. In the present study, we propose to explore the full range of the unit-sequence gradient and, as it turns out, a part of the letter-sequence gradient.

METHOD

The Lists

Two 12-unit serial lists were constructed of very high-frequency items. One of these lists consisted of three-letter words, the other of trigrams (three-letter units not forming words). The supposition was that the high-frequency words would have associative connections with other words in the list as well as with words not in the list. Thus, this list, according to the conception outlined above, would be subject to high interference from the unit-sequence gradient. The trigram list, on the other hand, would have relatively few associative connections with other units in the list or with units outside the list. However, both lists of items, because of their high frequency, should represent well-integrated letter sequences and thus be subject to minimal interference from the letter-sequence gradi-

ent. For these two lists the prediction is clear: the high-trigram list will be better retained than the high-word list.

To sample at another point on the unit-sequence gradient, two additional lists were constructed. Again, one of these consisted of three-letter words and the other of three-letter trigrams, but the frequency of occurrence in the language of the units in both lists was low. We did not in fact have a clear prediction concerning the retention of these lists simply because we did not have evidence concerning how far the letter-sequence gradient extends in an upward direction, nor how far the unit-sequence gradient extends in a downward direction along the meaningfulness scale. If the low-frequency trigrams are more subject to letter-sequence interference than the low-frequency words, and if the low-frequency words are but little subject to interference from the unit-sequence gradient, clearly the words should be better retained. But, it is also quite possible that the low-frequency words may be subject to interletter interference. Because of these unknowns, no specific prediction is made concerning the retention of these lists of low-frequency items. Rather, they were used in the hope that the results would give an indication about the likelihood of the gradients and, perhaps, their extent.

The four lists used are shown below. The lists are identified by frequency of items (Hi or Lo) and whether the units are trigrams (T) or words (W).

List Hi-W	List Hi-T	List Lo-W	List Lo-T
AGE	ATI	ADO	ARP
END	EST	COB	COF
HIM	HAN	DOE	DOP
NOT	NES	DUN	DUR
OLD	OME	EFT	ERF
OUR	OUN	FAD	FUM
RAN	RON	HIE	HEO
SHE	SHO	HOD	HOK
TEN	TES	LAX	LAK
USE	UND	RUT	RHA
WAS	WER	SAC	SIL
WIN	WHI	WRY	WYE

The words in List Hi-W are classified AA in the Thorndike-Lorge (1944) general count. The words in List Lo-W have a mean frequency of 2.75 per million in the same count. The Hi-T List consists of units whose average frequency in printed text is approximately the same as the frequency of the units in the Hi-W List when the frequency of the latter is counted both as to their occurrence as words and as parts of longer words. The same relationship holds for Lists Lo-W and Lo-T. The manner in which these frequencies were derived will be detailed in a forthcoming publication. However, one available source (Pratt, 1939) gives a rough approximation of the relative frequencies involved.

The choice of particular items for the lists was governed by two criteria in addition to frequency. The first dealt with formal intralist similarity, i.e., number of duplicated letters. By the nature of the materials involved we found it difficult to get an exact equation on this variable. The two high-frequency lists had a somewhat greater repetition of letters than did the low-frequency lists. The number of different letters used was 18, 17, 15, and 13, for Lo-W, Lo-T, Hi-W, and Hi-T, respectively. The number of duplicated letters in each position was approximately the same for all lists. The higher repetition rate for the high-frequency lists (as compared with low) occurred as a consequence of greater repetition of letters between first and second and between second and third positions.

The second criterion imposed in choosing items was that each be reasonably pronounceable. There was no attempt to equate lists on this variable; rather, the attempt was made to select items which were fairly easy to pronounce as opposed to items very difficult to pronounce.

During the course of running the experiment, other evidence suggested that pronunciability and rate of learning were positively related. Therefore, all 48 items were rated for pronunciability along a 5-point scale by 95 *S*s, none of whom served in the learning experiment. The *S*s were asked to rate the ease or difficulty of pronouncing each item relative to all the others, with a value of 1 representing the greatest ease, and 5 the greatest difficulty. The mean

values for the four lists were 2.02, 2.74, 2.31, and 2.77, for Hi-W, Hi-T, Lo-W, and Lo-T, respectively. As will be seen, these ratings have some predictive value for learning.

One other characteristic of the units used has been obtained. In handling the results the term *wordness* will be used to identify *lists* made up of words vs. lists made up of trigrams. A unit was considered a word if it appeared among the 20,000 most frequently used words in the Thorndike-Lorge (1944) list. Now in fact, not all words were identified as such by *S*s nor were all trigrams identified as *not* being words. Following relearning, each *S* was given a sheet on which all 24 trigrams and the 12 words from List Lo-W appeared in random order. The *S* was instructed to check each one which he thought was a word. Not a single word in List Lo-W was checked by all *S*s ($N = 144$) as being words. The mean percent checking each word was 61%. The word FAD was checked by 98.6% of the *S*s. At the other extreme, EFT was checked by 2.8%. Other relatively low percents were ADO, 41.0%, DUN, 39.6%, and HIE, 23.6%.

For List Lo-T every unit was checked by at least one *S* as being a word. The mean percent checking each unit was 5.7%. Those most frequently checked were FUM (13.9%), SIL (13.9%), and WYE (19.4%). For List Hi-T, on the other hand, four units were not checked by any subject. Omitting one unit from consideration, the mean percent checked was 1.0%. The one unit which was atypical was RON, which 68.1% of the *S*s checked as being a word. Thus, these data are fairly clear in indicating that the high-frequency trigrams used are less likely to appear to be words than are the low-frequency trigrams.

For the learning and retention tests the lists were presented in constant serial order at a 2-sec. rate. The anticipatory cue for the first unit was a single asterisk. Two blank spaces came between the last unit in the list and the asterisk so that the intertrial interval was 4 sec.

To avoid having the results tied to a particular serial order, six different orders were used. The rules used in constructing the orders were: (*a*) no unit appeared in the same serial position in different orders; (*b*) no two units appeared contiguously in more than one order; and (*c*) in none of the orders did adjacent units start with the same letter.

Subjects and Procedure

A total of 144 *S*s, all college students, were used in the experiment, being assigned to one of eight groups of 18 *S*s each. With a few exceptions, all *S*s were naive to verbal-learning experiments. A few *S*s (estimated at 5% of the total) had previously served in a verbal-learning experiment, but in all cases this had occurred at least 12 months prior to their present service.

Two groups were assigned to each list. For one group for each list, retention was measured 30 sec. following original learning; for the other, retention was measured 1 week following original learning. All *S*s in the 30-sec. groups also returned for a retention test after 1 week, but, of course, these retention data do not enter into the analysis. The original learning was carried to one perfect recitation for all groups for all lists.

The use of the 30-sec. retention interval provides a base for measuring forgetting over the week interval. If there are differences in rate of learning among the four lists, or if there are differences in the postcriterial drop (for any reason), the 30-sec. retention test provides a measure of degree of learning taken immediately after learning under conditions exactly comparable to the measurements made at 1 week. On both retention tests, relearning was carried to one perfect recitation or for five trials if the criterion was reached in less than five trials.

Instructions common to serial learning experiments were used with one exception. The *S*s both spelled and pronounced the units in making anticipations. The spelling always preceded pronunciation and *E* did not score the anticipation wrong if the pronunciation was late, i.e., if it occurred after the end of the 2-sec. anticipation interval.

In assigning the *S*s to lists, 18 blocks of eight entries each were used. Within each block, each list occurred twice, once as a 30-sec. retention condition, and once as a 1-week condition. Within the block the order was random. Each of the 6 orders used for each list was assigned to 3 *S*s, this assignment being made on a random basis for the 18 *S*s given a particular list and a particular retention interval.

The loss of *S*s in the experiment was relatively heavy. Indeed, 206 *S*s were run through at least part of the procedures in order to obtain 144 "good" *S*s. Two *S*s were lost for failure to learn, one of these for failure to learn the Hi-T List, one for failure to learn the Lo-W List. Forty-four *S*s were lost for miscellaneous reasons, e.g., not following instructions, failure to return

TABLE 1

TRIALS TO CRITERION AND DISTRIBUTION OF OVERT ERRORS IN ORIGINAL LEARNING

List	Trials to Criterion		Overt Errors per Trial		Mean Per Cent of		
	Mean	*SD*	Mean	*SD*	Intralist Errors	Other Errors	Partial Responses
Hi-W	29.97	10.72	1.29	.57	81.8	1.9	16.3
Hi-T	31.53	11.10	1.21	.62	68.4	12.0	19.6
Lo-W	29.50	8.74	1.23	.63	70.4	9.4	20.2
Lo-T	36.94	12.39	1.26	.57	50.7	25.9	23.4

for retention test, illness in the case of *E*, etc. These 44 *S*s were divided among the conditions as follows: Hi-W, 30 sec., 3; Hi-W, 1 wk., 5; Hi-T, 30 sec., 5; Hi-T, 1 wk., 7; Lo-W, 30 sec., 5; Lo-W, 1 wk., 6; Lo-T, 30 sec., 4; Lo-T, 1 wk., 9.

The final cause for loss of *S*s was rehearsal during the 1-week retention interval. In an attempt to mask the possibility that retention would be measured after 1 week, two additional tasks were inserted after original learning. One task consisted of a 5-min. test on number series progressions, and the other consisted of 3 min. of work on a simple card trick. Before *S* left the experimental room he or she was informed that 1 week later they would be measured on additional tasks. After *S* had relearned the list after 1 week, a nonpunitive interview was conducted concerning rehearsal during the week interval. If *S* had practiced the list more than three times orally, the records were not used in the final results. If the *S* had written down the items once, the records were not used. A total of 16 *S*s were rejected for such rehearsal. These were distributed as follows: Hi-W, 2; Hi-T, 4; Lo-W, 3; and Lo-T, 7.

Whenever an *S* was lost for any of the above reasons, the next *S* to appear was assigned to the list and retention interval of the *S* who was lost.

RESULTS

Speed of Learning

Table 1 shows the mean numbers of trials to criterion for the four lists. Since there were no significant differences between the groups tested after 30 sec. and after one week, the results of the two samples were combined, and each of the means in Table 1 is based on 36 *S*s. In spite of the diversity of the materials the variations in speed of learning are not extensive. Regardless of frequency, words are learned faster than trigrams ($F = 6.06$, 1 and 140 *df*, $.01 < P < .02$). Words of high and low frequency are learned at about the same rate. The Hi-T List has an advantage over the Lo-T List. Neither frequency nor the interaction of frequency with wordness (words vs. nonwords) is, however, significant. Two facts are worthy of emphasis. First, frequency of letter sequences in and of itself has only limited effects on speed of acquisition. Secondly, wordness overrides whatever effects of frequency are present. The rapid acquisition of the Lo-W List clearly supports these conclusions.

Speed of Learning as a Function of Pronunciability

Why does wordness, regardless of the frequency of letter sequences, favor acquisition? Our results suggest that it is not the frequency of the letter sequences but the frequency with which the items occur as integral units in the language which determines speed of acquisition. The fact that the Lo-W List is learned more rapidly than either the Hi-T List or the Lo-T List is consistent with this interpretation. The same argument would, however, also lead us to expect a large difference between the Hi-W List and the Lo-W

List. The items in the Hi-W List, which are among the most common words in the English language, certainly occur as units with vastly greater frequency than the items in the Lo-W Lists (which *S*s often fail to recognize as words). The contradiction is removed if we assume that in the learning of the Hi-W List the beneficial effects of frequency of occurrence were masked by interference from pre-experimental associations. We dislike to deal with theoretical mechanisms which oppose and perhaps balance each other in the learning process. Yet, at the same time, it is apparent that we must necessarily cope with this situation when the data demand it. A stage analysis (to be presented later) indicates that the items in Hi-W were more available than items in Lo-W, but the error analysis (also to be presented later) indicates that intralist unit interference was greater for Hi-W than for Lo-W. That we believe that these two opposing mechanisms were in balance in the present Hi-W list does not mean that such will inevitably be the case. That is, if a list were constructed in which the items were of the same frequency as those in the present Hi-W, but in which interunit associations were more numerous and stronger, we would clearly predict slower learning for such a list than for the present Hi-W.

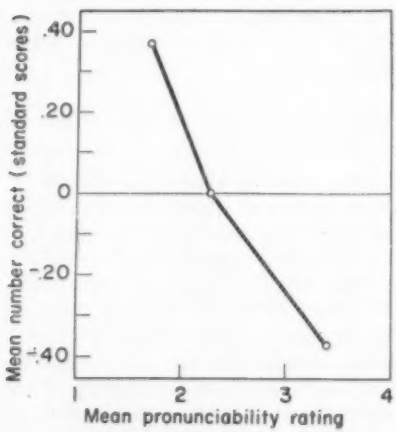

FIG. 1. Number of correct responses during learning (standard scores) for three groups of 16 items arranged in order of decreasing pronunciability.

The hypothesis that it is the frequency of occurrence of the units rather than of the letter sequences which is the critical variable in acquisition also receives support from an analysis of the relationship between pronunciability and speed of learning. Letter sequences which occur as integral units in the language are likely to be easier to pronounce than trigrams which occur as parts of other words. As we have seen, the lists of words were on the average rated as easier to pronounce than the lists of trigrams, and words were learned faster than trigrams. To establish a systematic relationship between pronunciability and speed of learning it is necessary to show, however, that the correspondence holds for individual items as well as lists. For this purpose, the 48 items included in the experimental lists were arranged in the order of their mean pronunciability ratings without regard to list membership. The total number of correct anticipations during learning was used to measure ease of acquisition for each item. To make these measures comparable across lists, the anticipation score of each item was expressed as a deviation, in *SD* units, from the mean anticipation score of all the items in a given list. Since there were only six orders per list, these standard scores are not entirely balanced for the effects of serial position. The resulting bias can be minimized, however, by a grouping of items. Figure 1 shows the relationship between pro-

nunciability and ease of learning when the distribution of pronunciability ratings is divided into successive thirds. It is clear that the direct relationship found with total lists holds for individual items when list membership is ignored. The strength of this relationship is assessed by the coefficient of correlation between pronunciability ratings and anticipation scores. The correlation for individual items, which takes no account of serial-position biases, is .28 ($.02 < P < .05$). When the bias is reduced by computing the correlation for successive pairs of items arranged in order of pronunciability the value of r becomes .46 ($.01 < P < .02$). We conclude that (*a*) speed of learning is a function of pronunciability, and (*b*) the association between wordness and ease of pronunciation is one of the factors responsible for the observed differences in speed of learning.

Errors during Learning

The mean numbers of overt errors per trial are presented in Table 1. Overt errors include intralist errors (correct units given in an incorrect position), three-letter responses not in the list ("other errors"), and partial responses. The rate of overt errors is virtually identical for the four lists. While the over-all error rate is the same, the relative frequencies of the different kinds of errors vary from list to list. The percentage which each kind of error was of the total errors was determined for each *S*, and the means of these percentages are shown in Table 1. The relative frequency of intralist errors is greatest for the Hi-W List and smallest for the Lo-T List, with the Hi-T and Lo-W Lists yielding intermediate values. Thus, the percentage of intralist errors is a function of both frequency and wordness. The rank order of the conditions suggests that the rate of intralist errors varies with the availability of the items as response units. Availability of the responses is also an essential condition of anticipation learning. To the extent that both correct anticipations and intralist errors depend on response availability, speed of learning and percentage of intralist errors should be positively related. Such a positive relationship does, in fact, obtain when words and trigrams are compared. The same pattern holds for the two lists of trigrams but not for the two lists of words. One possible interpretation is that when a serial list is composed of items from *S*'s linguistic repertoire, the relative frequency of intralist errors will reflect not only the availability of the responses but also interferences from pre-experimental associations which compete with the prescribed responses. Thus, the items in the Hi-W List are not only the most available responses but also the most likely to be linked through pre-experimental learning. As a result, the percentage of intralist errors is higher for the Hi-W List than the Lo-W List but there is no corresponding difference in speed of learning.

The percentages of three-letter responses not in the list vary *inversely* with both frequency and wordness. Such errors hardly ever occur during the learning of the Hi-W List but constitute a substantial proportion of the errors made by *S*s learning the Lo-T List, with the Lo-W and Hi-T Lists again yielding intermediate values. The rare cases which occurred during the learning of the Hi-W List could readily be identified as instances of response generalization (HER replacing SHE, HIS replacing HIM, etc.) or transpositions of letters during the spelling of a word. Many of the errors made during the learning of the

other three lists, on the other hand, pointed to persistent difficulties of response integration. Occasionally four-letter responses were given, especially on the early trials of learning. If these errors are taken as evidence for interference from *S*s' letter-sequence habits, the large difference between the Hi-T List and the Lo-T List readily falls into place. Response integration is also a source of some difficulty in the learning of the Lo-W List but the use of easily pronounceable units appears to make the problem much less severe than for the Lo-T List.

Partial responses may include slow correct responses as well as incomplete errors. Since a given letter could be correct in more than one position, a precise classification and interpretation of partial responses are not possible.

Stages of acquisition. Learning cannot occur unless the appropriate responses are available to *S*. At the same time, however, the probability of intralist errors may increase with response availability. In accounting for the correlation between the rate of correct responses and misplaced responses it is useful to make an analytic distinction between two successive stages of learning (Underwood, Runquist, & Schulz, 1959). The first stage is one of response integration during which the items in the list become available to *S* as responses. If the items are not already in *S*'s repertoire the prescribed letter sequences must be acquired during that stage. The greater the positive transfer from *S*'s pre-experimental habits the shorter will be the stage of response integration. The trial on which a response is first given, whether in the correct or incorrect position, may be used to measure the speed of response integration. The second stage is an associative one in which the response is connected with the appropriate stimulus, e.g., in serial learning to the preceding item. The number of trials separating the first occurrence of the response anywhere in the list from its first occurrence in its correct position provides a measure of the difficulty of the associative stage. While the distinction is useful for analytic purposes, it is recognized that both stages are likely to proceed concurrently: associative connections begin to be built up during the integrative stage, and response integration continues during the associative stage.

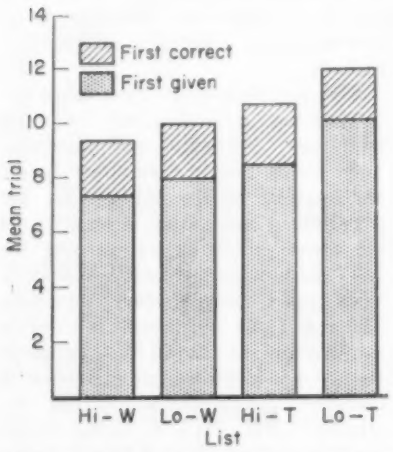

FIG. 2. Mean trial on which each kind of item was first given and mean trial of first correct anticipation.

The correlation between correct responses and intralist errors suggests that the lengths of the two stages need not necessarily be related. Figure 2 does, in fact, reveal such a lack of relationship. In that figure, we have shown for the four sets of material the mean trial on which responses were first given in any position and the mean trial on which they were first given in the correct position. There are substantial differences in the speed with which different kinds

of responses become available. Words are given earlier than trigrams, and within each of these two classes high-frequency items are given more rapidly than low-frequency items. There are no comparable differences in the length of the associative stage. The time which elapses between the first appearance of a response and its first correct placement is roughly equal for all materials. The difference between the two measures is, in fact, smallest for the Lo-T List where response integration is believed to proceed most slowly. This pattern is fully consistent with the relationships found in the analysis of the errors.

Recall. The mean numbers of items anticipated correctly on the first trial of relearning are shown in Figure 3. The results of the 30-sec. test show clearly that attainment of a fixed criterion does not imply constant associative strength, and that the magnitude of the postcriterial drop must be taken into account in assessing long-term retention loss (Underwood, 1954). In agreement with the assumption that associative strength at criterion varies directly with rate of acquisition, immediate recall is higher for the two lists of words than for the two lists of trigrams. The correspondence between rate of acquisition and immediate recall also holds for the two lists of words: equal rates of acquisition are followed by equal amounts of recall after 30 sec. Comparison of the two lists of trigrams, however, reveals a discrepancy. Although the Hi-T List was learned faster than the Lo-T List, the amounts recalled are virtually identical. This finding suggests that for the Hi-T List one perfect recitation represents a less stable criterion of performance than for the other lists. Internal evidence from the learning records which supports this conclusion will be presented below.

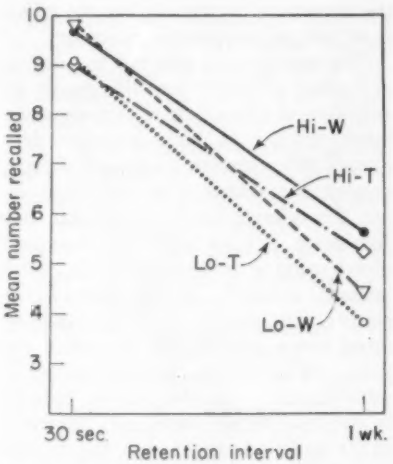

FIG. 3. Mean numbers of correct responses on first trial of relearning.

Retention after one week appears to be poorer for the two low-frequency lists than for the two high-frequency lists. For both words and trigrams, equal performance on the 30-sec. test is followed by a difference in favor of the high-frequency list after one week. At both levels of frequency, words and trigrams suffer comparable losses at recall. The mean differences between the 30-sec. and 1-week groups which represent the amount of retention loss are as follows: Hi-W, 4.11; Hi-T, 3.83; Lo-W, 5.39; Lo-T, 5.23. Analysis of variance fails to reveal any significant differences in the amount of retention loss as assessed by the interaction of lists with interval. The *F* ratio which approaches significance most closely is that for the interaction of frequency with interval. The obtained value of *F* is 3.29, whereas 3.91 is required at the .05 level with 1 and 136 *df*. The total recall scores suggest, therefore, that differences in letter-sequence interference influenced

the amount of forgetting but the effect is at best of marginal significance.

The recall scores also fail to provide any clear evidence for differences in retention as a function of unit-sequence interference. At both levels of frequency the retention losses are slightly greater for words than for trigrams but the differences are small and not significant. Thus, the first measure of retention to be examined, viz., total amount recalled, yields inconclusive results with respect to letter-sequence interference and largely negative results with respect to unit-sequence interference. All the trends present in the total recall scores are, however, in the direction predicted by the theory. We shall now present further analyses which bring out these trends more clearly and significantly by means of measures which proved more sensitive to the variables manipulated in the experiment.

Recall as a Function of Serial Position

Interference effects may be expected to vary as a function of the serial position of the items to be recalled.

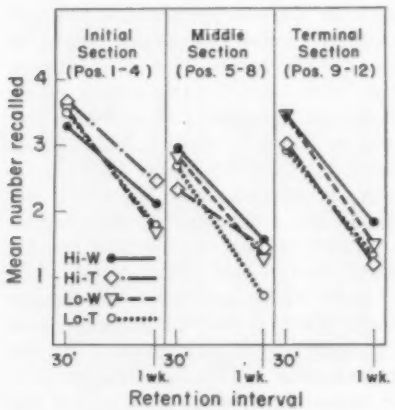

FIG. 4. Mean numbers of correct responses for different sections of the list on the first trial of relearning.

There are several reasons for this expectation. First, strength of learning at criterion varies as a function of serial position. After a given retention interval, the absolute level to which the items have been learned may determine the sensitivity of the recall test to the effects of interference. Pre-experimental habits may recover slowly, and items which have received relatively few reinforcements during acquisition are more likely to reveal interference from extraexperimental sources than those which have been substantially overlearned. Secondly, the recall trial is also a learning trial. The improvement which occurs in the course of that trial may facilitate the recall of different materials to unequal degrees. Thus, interference from intralist errors may be progressively reduced during the first re-exposure to the series whereas letter-sequence interference might not. Finally, the degree of sequential dependency among the items should critically influence the results of the recall test. The greater the degree of sequential dependency the more serious will be the cumulative effects of failures in the early part of the series.

In the light of these considerations, the results of the recall tests were examined separately for the initial (Serial Positions 1–4), middle (Positions 5–8) and terminal (Positions 9–12) sections of the lists. The relevant data are presented in Figure 4. Prior to statistical analysis, the recall scores for the three sections of the list were subjected to a Freeman-Tukey square-root transformation in order to remove heterogeneity of variance. Analysis of variance shows the higher-order interaction, Interval × Sections × Frequency × Wordness to be significant ($F = 3.34$, 2 and 136 df, $.02 < P < .05$). The variations in relative retention loss which occur from sec-

tion to section may therefore be considered reliable. Further tests of significance will be presented in connection with the discussion of the results for each section.

Initial section. In the initial section of the list the low-frequency materials are forgotten more rapidly than the high-frequency materials. The interaction of frequency with interval is significant ($F = 4.84$, 1 and 136 *df*, $.02 < P < .05$). The low-frequency items would (according to the theory) be more subject to letter-sequence interference than the high-frequency units. The latter, in turn, should be more subject to unit-sequence interference. Thus, this interaction may mean that letter-sequence interference is greater than unit-sequence interference at these serial positions. That there is some unit-sequence interference is suggested by the fact that the high-frequency trigrams are recalled better than the high-frequency words on both the immediate and the delayed test. Recall for the Hi-W List is, indeed, somewhat poorer than for any other material in spite of the fact that the Hi-W List was learned faster than the Hi-T and the Lo-T Lists and at about the same rate as the Lo-W List. A possible interpretation is that some of the strongest pre-experimental associations which gave rise to persistent intralist errors during learning were not extinguished sufficiently and recovered during the 30-sec. interval. Such interferences would be most detrimental to the recall of the early section of the list, i.e., before the context of the series had been re-established. If this interpretation is correct, some of the losses attributable to unit-sequence interference are reflected in the control measures rather than the long-term retention scores.

Middle section. In the center of the list, immediate recall is better for words than for trigrams. The difference found in the initial section between the Hi-W and the Hi-T List is reversed. The Lo-W List begins to show an advantage over the Lo-T List. With reference to this baseline, there is evidence for both kinds of interference. The high-frequency lists are retained better than the low-frequency lists. The interaction of frequency with interval is significant ($F = 4.27$, 1 and 136 *df*, $.01 < P < .05$). This finding is again consistent with the assumption of differential letter-sequence interference. As Figure 4 shows, however, it is primarily the superior retention of the high-trigram list which is responsible for this interaction. Indeed, the Hi-T List is retained better than any other list. The fact that the Hi-T List suffers less loss than the Hi-W List gives the most direct support thus far for differential unit-sequence interference.

Terminal section. In the terminal section of the list, words are recalled better than trigrams both after 30 sec. and after 1 week. Summed over the two intervals, the difference between words and trigrams is significant ($F = 6.12$, 1 and 136 *df*, $.01 < P < .02$). That words are better recalled than trigrams appears to be a function of differences in sequential dependencies, a matter to which we will turn shortly. There is a somewhat greater loss for the low-frequency words than for the other materials but there are no significant differences in the amount of forgetting.

The trends revealed by the sectional analysis may now be summarized. First, significant variations in the rate of forgetting as a function of the characteristics of the materials are limited to the first two sections of the list. The recall scores for these sections provide evidence for differences in both letter-sequence inter-

ference and unit-sequence interference. Secondly, as we proceed from the beginning to the end of the list, words gain an increasing advantage over trigrams in immediate recall. In the final section, this difference is most pronounced, is maintained after one week, and accounts for substantially all the observed differences in recall. Thus, as the end of the list is approached, wordness per se becomes the primary determinant of both immediate and delayed recall and overrides the influence of other variables. This interaction between list section and the other variables explains the inconclusive results obtained with total recall scores.

Sequential Dependencies

The superiority of the words in the final section suggests that a list of words is characterized by a lower degree of sequential dependency than is a list of trigrams. That is, the correct anticipation of a word is less dependent on the context provided by correct reproduction of the preceding items than is the correct anticipation of a trigram. Two possible reasons for such a difference in sequential dependency may be mentioned. First, words which are well integrated and become readily available as responses may be more easily associated with specific serial positions than trigrams. Association between a single item and a *specific* serial position makes anticipation relatively independent of preceding responses. Secondly, to the extent that words have higher *m* value (Noble, 1952) than trigrams of comparable frequency, associations between adjacent words may be more independent of serial position than associations between adjacent trigrams. As a result, the loss of weakly learned items in the middle of the list would detract less from the recall of relatively strong terminal items in a list of words than in a list of trigrams.

To support our interpretation, independent evidence is required for the assumed difference in sequential dependency. Such support is provided by (*a*) an analysis of serial position effects in learning, and (*b*) evidence for differential degrees of sequential dependency in the recall of words and trigrams. Turning to learning first, we have used the number of increases between adjacent serial positions to quantify the degree to which linkages between successive items were independent of the serial context. As *S* progresses from the beginning to the end of the list, the probability of a correct anticipation typically decreases, until there is a rise in the terminal positions. In a list with a high degree of sequential dependency there should be few reversals in this trend, i.e., rises between positions in a falling section of the serial position curve. By the same token, a high degree of sequential dependency should delay the onset of the terminal rise. To the extent that successive associations are relatively independent of the preceding serial context, rises between adjacent serial positions should become more probable. The number of such rises was, therefore, determined for the serial position curve of each individual *S*. The mean numbers of rises per *S* for the four lists were as follows: Hi-W, 4.94; Hi-T, 4.30; Lo-W, 5.06; Lo-T, 4.47. The difference between words and trigrams is significant ($F = 8.43$, 1 and 136 *df*, $P < .01$). The difference in the frequency of rises is consistent with the hypothesis that associations between adjacent words are less influenced by the preceding context than are adjacent associations between trigrams. The same hypothesis leads to the expectation that for words the recall of items from the terminal

section should be less contingent on prior recall of central items than for trigrams. The results of the one-week tests, which show a wider range of individual variations than the 30-sec. tests, were used to verify this implication. In Figure 5 the mean number of correct responses in Section 3 is plotted as a function of the number of responses obtained in Section 2. There is a clear positive correlation for the two lists of trigrams whereas for words recall of Section 3 is virtually independent of the number of correct responses in Section 2. This finding further supports the hypothesis of differences in the degree of sequential dependency between words and trigrams.

Relearning

The mean numbers of trials to criterion in relearning are shown in Figure 6. Inspection of the figure immediately calls attention to a salient feature of the results, viz., the divergence between the Hi-T List and all other lists. After 30 sec., the Hi-T List is relearned appreciably more slowly than the other lists. After one week, this relationship is completely reversed. As measured against the 30-sec. baseline, therefore, the relearning scores show very little forgetting of the Hi-T List and major losses for the other lists. The interaction of lists with interval is significant ($F = 3.33$, 3 and 136 *df*, $.01 < P < .02$). The finding that the high-frequency trigrams are relearned faster than any of the other materials is, of course, in full agreement with the prediction made by an interference theory of forgetting.

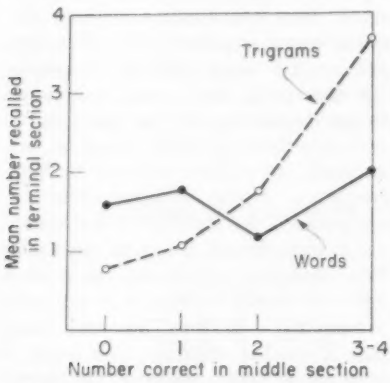

FIG. 5. Mean numbers of correct responses in terminal section as a function of the number of correct responses in the middle section (1-wk. recall tests).

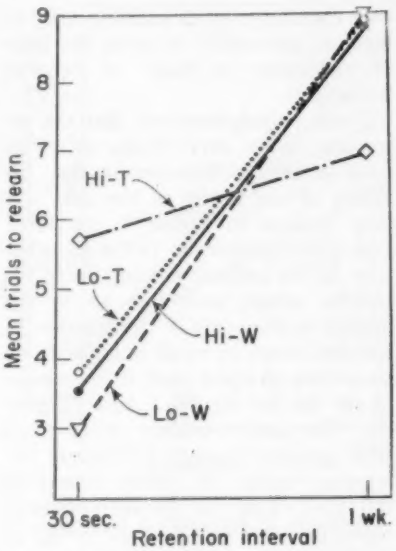

FIG. 6. Mean numbers of trials to relearn to criterion.

Before this result is accepted at face value, we must find an answer to the puzzle posed by the unexpectedly slow relearning of the Hi-T List after 30 sec. It must be shown that the results of the immediate relearning do, indeed, adequately represent the strength of the Hi-T List shortly after attainment of the criterion. Any conclusions concerning differential rates of long-term forgetting depend, of course, on the validity of the 30-sec. control measure.

Our confidence in its validity rests, in turn, on our ability to relate the facts of relearning to those of original learning.

Further analysis shows that the relearning scores after 30 sec. reflect almost entirely differences in the difficulty of the center of the list. As may be seen in Figure 4, the Hi-T List falls substantially below all other lists in the amount recalled from the middle section and does so in the middle section only. The number of intralist errors at recall is highest and shows the sharpest peak in the center of the list for the Hi-T List (Figure 8). The pattern evident on the recall trial persists through subsequent relearning trials: the group relearning the Hi-T List has greater difficulty than any other group in the center of the list and continues to make more intralist errors (Figure 9). The fact to be accounted for narrows down, therefore, to the persistent difficulty of the center of the Hi-T List in relearning after 30 sec.

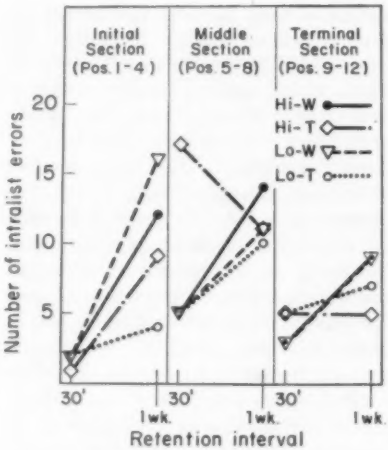

FIG. 8. Total frequency of intralist errors for different sections of the list on first relearning trial.

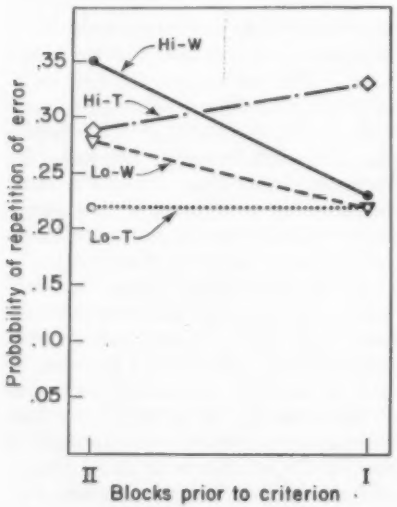

FIG. 7. Probability of repetition of intralist errors in last two blocks of five trials preceding criterion trial.

Examination of the original learning records has led us to the conclusion that the instability of the Hi-T List at criterion stems from the combination of high response availability and low meaningfulness which is characteristic of these materials. The items in the Hi-T List represent extremely frequent letter sequences and, therefore, are readily integrated as responses. As nonwords, they may be assumed to have relatively low meaningfulness; certainly their *m* values must be substantially lower than those of the high-frequency words. Under these circumstances, the stability of the associative connections between successive items does not keep in step, as it were, with the rapid increases in response availability. It then becomes likely that *S* reaches criterion at a point in learning at which some of the associative connections, especially those in the center of the list, are still extremely unstable and liable to be lost on the

postcriterial trial. Put differently, because of high response availability *S*s learning the Hi-T List are likely to reach criterion by "overshooting the mark" in the final stages of learning but because of the low meaningfulness of the items they will have difficulty in regaining criterion during relearning.

Our interpretation finds support in a number of independent analyses. First, there are greater cyclical fluctuations during the learning of the Hi-T List than of the other lists. Cyclical learning curves similar to those described by Underwood (1957b) were plotted for each of the four lists. These curves clearly showed more extensive fluctuations in the magnitudes of the postcriterial drops for the Hi-T List than for the other lists. The observed differences in relearning appear to be consistent with the long-term trends characteristic of these curves. Secondly, a comparison between fast and slow learners shows that the relationship between speed of learning and relearning is quite different for the Hi-T List and the other lists. According to our analysis, it is the fast learners of the Hi-T List who reach criterion during an exaggerated spurt and who are mainly responsible for the decrements in immediate relearning. Contrary to the usual relationship, therefore, fast learners of the Hi-T List should take longer to relearn and make more intralist errors than slow learners.

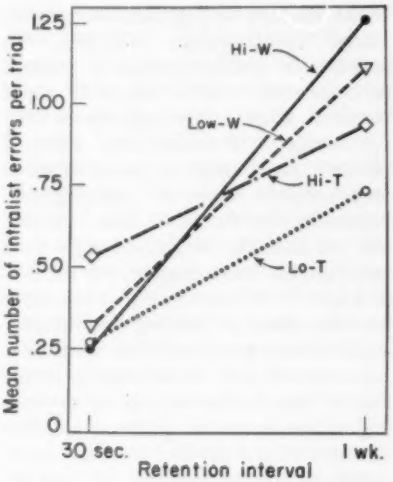

FIG. 9. Mean numbers of intralist errors per trial in relearning to criterion.

Table 2 presents a set of measures which is consistent with this interpretation. The percentage of the total learning time required to go from a criterion of 10/12 to one perfect recitation was used to assess the degree of criterial end spurt. In the case of the Hi-T List, the percentage is considerably lower for fast than for slow *S*s. The difference is in the same direction but smaller for the Lo-T List and is reversed for the two word lists. Thus,

TABLE 2

MEASURES OF PERFORMANCE OF FAST AND SLOW SUBJECTS IN LEARNING AND RELEARNING

List	Per Cent Learning Time from 10/12 to 12/12		Trials to Relearn After 30 Sec.		Intralist Errors per Trial in Relearning	
	Fast *S*s	Slow *S*s	Fast *S*s	Slow *S*s	Fast *S*s	Slow *S*s
Hi-W	27.2	18.2	2.44	4.67	1.75	2.76
Hi-T	16.2	27.1	7.56	3.89	5.81	3.66
Lo-W	24.0	22.3	2.22	3.78	2.50	3.25
Lo-T	20.9	26.5	4.67	3.00	2.18	2.75

in the learning of trigrams, and particularly high-frequency trigrams, the speed with which criterion is reached is correlated with a relatively rapid terminal stage. The opposite is true for words. As anticipated, Table 2 shows a pronounced negative relationship between speed of learning and relearning for the Hi-T List. A similar relationship obtains, though to a considerably lesser degree, for the Lo-T List. With words, the relationship between speed of learning and relearning is clearly positive. The differences between fast and slow learners in the rate of intralist errors during relearning follow a similar pattern, i.e., fast learners of the Hi-T List make more errors than slow learners, whereas the opposite is true for the other groups. As regards intralist errors, therefore, the group learning the Lo-T List no longer behaves like the group learning the Hi-T List. As was shown earlier, however, the rate of intralist errors is less critical in the learning of the Lo-T List than the Hi-T List. With the low frequency materials, other three-letter errors reflecting difficulties of integration are a more sensitive index. With respect to such errors, fast *S*s do, in fact, surpass slow *S*s (.28 vs. .11).

A final analysis is directed at an explanation of the unusually large number of intralist errors given during the recall of the Hi-T List after 30 sec. It appeared possible that the combination of high-frequency letter sequences and low meaningfulness would be conducive to a growth of error tendencies late in learning when the appropriate responses were fully available to *S*s but interitem associations were still weak. To test this possibility, the development of intralist errors during the last 10 trials preceding criterion on each of the lists was subjected to a detailed analysis. These 10 trials were divided into two blocks of five each. Within each block, the probability of repetition of an intralist error was investigated, i.e., the ratio of repeated intralist errors to total number of different errors was determined. The results are shown in Figure 7. As criterion is approached, the probability of an error being repeated declines in the word lists. It remains at a steady, relatively low level in the Lo-T List. It is only in the Hi-T List that the probability of error repetition actually increases in the final precriterial stage. During the last block of five trials, therefore, the probability is considerably higher for the Hi-T List than for the other three lists which yield virtually identical values. It may be noted that the two subsamples of 18 *S*s learning a given list gave comparable results for all lists. The relative frequencies of intralist errors at 30-sec. recall, which are heavily weighted by responses in the middle section, are predicted reasonably well from the trends in Figure 7.

Examination of the internal evidence thus leads us to accept the interaction shown in Figure 5 as valid and to consider the losses measured by relearning a function of differential interference. The Hi-T List suffers some extremely rapid losses, the reasons for which we have attempted to trace back into the process of acquisition. Whatever is not lost immediately is, as predicted, relatively immune from long-term outside interferences.

DISCUSSION

The experiment was designed to examine the implications of two assumed interference gradients, namely, a unit-sequence gradient and a letter-sequence gradient. We will first examine the credibility of assuming a

unit-sequence gradient in light of the results of the experiment.

The assumption was that List Hi-W would be more susceptible to unit-sequence interference in retention than would List Hi-T. The word list, made up of frequently used words, should have fairly strong associative connections among units within the list (e.g., OLD-AGE) as well as have strong associations with words not in the list. The high-frequency trigrams, on the other hand, should have relatively few such associations and yet at the same time they should be readily available because of their high frequency. If it is assumed that the pre-experimental associations of List Hi-W have to be extinguished during learning, and that these extinguished associations recovered during the retention interval, the retention of List Hi-W should be inferior to List Hi-T. The recovery of the associations during the retention interval should, furthermore, be augmented by the use of the words in List Hi-W in new and old contexts during the retention interval.

The question may be raised as to whether the assumed differences in the nature of the two lists are reasonable. We do not have association data to document our presumption that the units in the word list were more highly connected pre-experimentally than were the trigrams. Nor do we have data to indicate that the words had more associations outside the list than the trigrams. However, in addition to a fairly self-evident impression on these matters obtained from inspecting the list, and in addition to the known fact that the greater the frequency of a word the greater the number of associates it has, internal evidence in support of the different characteristics ascribed the two lists is available. The single most relevant datum is the greater number of intralist errors which occurred in learning List Hi-W than List Hi-T. Although we did not present the data, it can be reported that these intralist errors occurred with high frequency very early in learning List Hi-W and then gradually diminished in frequency as learning proceeded. This high initial occurrence of such errors may be attributed to the associative connections existing among the items at the start of learning. List Hi-T, on the other hand, was actually producing an increase in repetitive intralist errors as original learning approached termination.

In view of these trends in intralist errors, it might be asked why List Hi-T was not learned more rapidly than List Hi-W. There are two facts which suggest why this did not occur. First, there was some evidence that the high trigrams produced some integrative (letter-sequence) errors early in learning. Secondly, if it is accepted that items in List Hi-T have relatively few interitem associations at the start of learning, then, it follows that in Noble's sense (1952) they have low *m* value (a relatively small number of associates as such). Insofar as *m* is related to learning, the Hi-T List should be learned more slowly than the Hi-W List.

If it be assumed, in light of the above comments, that the Hi-W and Hi-T Lists do have the differential characteristics necessary to make a test of the item-sequence gradient of interference, the critical question is how well the retention results support the expectation from the theory. In terms of recall of correct responses, the only clear-cut support of the theory occurred in the middle serial positions. Here, the loss was greater for List Hi-W than for List Hi-T. In the initial serial positions the Hi-T List was better recalled than the Hi-W List at both retention intervals, but there

was no difference in the amount lost over the week. In the final serial positions, the Hi-W List was better recalled at both intervals but again there was no differential loss.

The argument that has been advanced would predict that the frequency of intralist errors should show a greater increase over the week for List Hi-W than List Hi-T. That this is the case is shown in Figure 8, where intralist errors at recall for all lists for both retention intervals are shown. In every section the increase in intralist errors is appreciably less for List Hi-T than for List Hi-W. In the middle serial positions there is actually a decrease in the frequency for List Hi-T, but since we have made no statistical tests it may be best to speak of no change in frequency.

If, as shown in Figure 8, intralist error tendencies recover less for the Hi-T List than for the Hi-W List, why is the over-all forgetting (in terms of correct responses) of the Hi-T List not less than for List Hi-W? The answer is found, we believe, in the greater number of sequential dependencies built up in learning List Hi-T than in learning List Hi-W. In the results section it was shown that in the learning of the trigram lists correct anticipation of a given response is more dependent upon earlier correct anticipations than is true for the word lists. We have suggested that this is due to the differences in *m* value. But, whatever the reason, it can be seen that the failure to get one response at recall reduces the probability of recalling a subsequent response, and this reduction is greater for the trigram lists than for the word lists. This difference in sequential dependency was unexpected and, as far as we know, previously unreported, but it seems clearly to produce an outcome which works against the recall data showing clear confirmation of the unit-sequence gradient. Since relearning should be much less influenced by this factor than recall, we turn to these relearning data as being a more pure case of the operation of the unit-sequence interference gradient.

It will be remembered that the relearning data showed less forgetting of List Hi-T than of the other lists. Does the change in frequency of intralist errors correspond to the theory and hence to the relearning scores? The answer can be found in Figure 9. The increase in intralist errors over the week interval is apparently greater for the word lists than for the trigram lists. This plot gives intralist errors per trail during relearning to the criterion. After 30 sec., many of the *S*s made no errors during relearning. In order to get some notion of the reliability of the change from 30 sec. to 1 week in these intralist errors, 30-sec. *S*s and 1-week *S*s were paired for a given type of list, the pairing being based on the random order used to assign *S*s to lists originally. From these pairings change scores could be derived. For the 36 *S*s learning the two word lists the mean change in intralist errors per trial was .91; for those learning the trigram lists the mean change was .45. The difference gives a t of 2.88, significant beyond the .01 level. It thus seems reasonable to conclude that intralist errors increase more rapidly for the word lists than for the trigram lists. We conclude, further, that this fact gives substance to the notion of the unit-sequence gradient in forgetting. The trigrams, having minimal pre-experimental associative connections among themselves or with units not in the list, are not subjected to interference from the unit-sequence gradient as much as are the word lists.

We turn next to an evaluation of the

other assumed gradient—the letter-sequence gradient. Is there evidence for a recovery process leading to interference *within* the responses?

Letter-sequence interference would be documented by three-letter sequences which are more frequent in the language than the responses they replace. As an illustration, consider an error which occurred with some frequency in List Lo-T during learning. The correct response was LAK, the substituted response, LAC. LAC is a much more frequent letter sequence in the language than is LAK. Thus, this might be considered a relatively pure case of letter-sequence interference. Other kinds of three-letter errors cannot be so easily interpreted. For example, ARF occurred very frequently as an error, apparently as a merger of ARP and ERF. ARF is a very low-frequency trigram, although RF is a much more frequent two-letter sequence than is RP. Thus, given AR, F is a more probable response than is P. But it is a fact that very few letters are imported and overtly produce interference, i.e., nearly all wrong sequences involve letters actually in the list. This means that evidence of overt interference must be limited to intra-unit interference from letters within the list. Many of these errors can be shown (as illustrated above) to consist of a least two-letter sequences which are more frequent (hence, are assumed to have higher associative strength) than the sequences they replace. Some cannot.

A consideration of the structure of the lists together with the error results may suggest that we are simply dealing with intralist formal similarity defined by letter duplication. It is known that for nonsense syllables intralist formal similarity has a greater effect in learning low-meaningful items than in learning high-meaningful items,

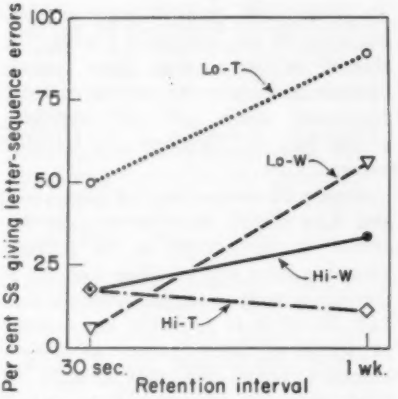

FIG. 10. Percentages of *Ss* giving letter-sequence errors in relearning.

but there is little differential effect on retention (Underwood & Richardson, 1956; Underwood & Richardson, 1958). In the present study the low-frequency lists (Lo-T and Lo-W) show a greater loss at recall over the week than do the high-frequency lists. The differences are significant statistically for the first two sections (Serial Positions 1–8, see Figure 4). The nature of the errors, as explained above, does not allow us to decide whether this effect is produced by error tendencies resulting from formal intralist similarity, by stronger letter-sequence habits, or both. It is worth pointing out, however, that List Hi-T had greater formal similarity than either Lo-T or Lo-W and yet we find little evidence for letter-sequence errors in retention. So, while we are inclined against formal intralist similarity as the critical factor, our data do not allow us to make a clear decision.

In spite of the interpretative problems, we can show that letter-sequence errors do increase over the retention interval. This increase is most clearly seen in the relearning data. Because many *Ss* gave no such errors at 30 sec., we have plotted the per cent of

*S*s giving such errors during relearning after 30 sec. and after 1 week. It should be clear that these errors plotted in Figure 10 are three-letter responses which are not responses in the list, i.e., they are not intralist errors.

Figure 10 shows that for List Lo-T and List Lo-W there is a clear increase in percentage of *S*s making letter-sequence errors. For List Hi-T there is actually a slight decrease. For List Hi-W it is probably not correct to speak of these errors as letter-sequence errors for they consist in most cases of what we have called generalized responses, e.g., HER for SHE, WON for WIN, WERE for WAS. Finally, we may note that the higher frequency of letter-sequence errors in List Lo-T than in Lo-W is balanced by fewer intralist errors in Lo-T than Lo-W (Figure 9) and that relearning time is about the same in both instances.

Our conclusion concerning the letter-sequence gradient is that the evidence supports the plausibility of such a gradient but that we cannot rule out completely the possibility that the results could be attributable to formal intralist similarity without any need to appeal to letter-sequence habits which *S* brings to the situation. Only by using lists in which no duplicated letters occur can this separation be made clearly.

The present study has given some evidence that extraexperimental sources of interference can be treated analytically. The critical requirement is to know what associations the subject brings to the laboratory and then present him with a task where these associations will have to be broken, inhibited, or extinguished. The lists used in the present study were believed to meet this requirement, although, as pointed out earlier, it would be quite possible to show this more clearly than we have. We have suggested two sources of interference—two classes of associations—which *S* may bring to the laboratory. List Lo-T was primarily used to illustrate the letter-sequence habits which *S* brings with him; List Hi-W to illustrate the unit-sequence habits; List Hi-T the minimum of either kind of habits; and, as the data turned out, List Lo-W seems to have elicited a fair number of both types of habits.

The assumption of a recovery of inhibited or extinguished associations was a fundamental part of our thinking and of the analyses made. Will all types of habits recover at the same rate? Is one week long enough to expect an appreciable recovery to occur? These are merely suggestive of the questions which will need to be answered if extraexperimental sources of interference in forgetting are to be systematically evaluated.

SUMMARY

This paper examines two major sources of extraexperimental interference in long-term forgetting: (*a*) letter-sequence interference which is produced by well established associations between letters in *S*'s language, and (*b*) unit-sequence interference which reflects pre-experimental associations among the units of a list. Both types of interfering associations must be extinguished during the acquisition of a serial list and are assumed to recover during the retention interval. Differential rates of forgetting are predicted for materials varying in susceptibility to the two kinds of extraexperimental interference.

An experiment testing these assumptions is reported. Four kinds of three-letter units were used in a serial learning task: high-frequency words,

high-frequency nonsense items (trigrams), low-frequency words and low-frequency trigrams. Retention was tested 30 sec. after the end of practice and after one week. It was assumed that letter-sequence interference would be greater for low-frequency than high-frequency units whereas unit-sequence interference should be greater for words than nonwords. Speed of acquisition was greater for words than for trigrams. The differences in long-term retention, measured at recall and in relearning, and supplemented by an analysis of overt errors, gave support to the present analysis of the conditions of extraexperimental interference.

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REANALYSIS OF "IMPRESSIONS OF PERSONALITY"

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Introduction

The problem of how we come to know others concerns and has concerned many psychologists. However, until Asch (1946) reduced part of this problem to manageable proportions, it was relatively refractory to experimental analysis. The studies to be reported in this paper were directed to the clarification of some of the theoretical questions posed by Asch, and particularly, to the problem of the operational analysis of Asch's concepts of "central" and "peripheral" traits.

One of Asch's more important contributions was to devise an experimental procedure whereby the general problem is formulated in linguistic terms. Thus, the experimental question posed is how a series of discrete trait-names read to a subject (*S*) is transmuted into a unified impression; or more specifically, what is the effect on the final impression of changing one trait or another into its opposite, holding other elements of the stimulus list, or information input, constant. For example, in one experiment, one group of *S*s were told that a certain person was "intelligent-skillful-industrious-warm-determined-practical-cautious"; another group heard the same list, but with "cold" substituted for "warm." These two groups appeared to form markedly different impressions, and this was demonstrated quantitatively by obtaining ratings on an 18-item check list composed of pairs of opposed trait names, e.g., Generous–Ungenerous, Strong–Weak, etc. On the other hand, varying Polite–Blunt in the same context as Warm–Cold produced fewer and apparently only minor differences between groups. Asch (1946) argued, therefore, that a trait in the stimulus list can be either "central" or "peripheral" in its influence on the final impression, depending on the context in which it is imbedded, although not all traits can assume "central" positions in this sense.

Most of the subsequent experiments evoked by Asch's original study have been reviewed by Asch (1952, ch. 8) and by Bruner and Tagiuri (1954) and need no further comment here. Asch's direct findings seem quite reliable and have been confirmed in several studies (e.g., Mensh & Wishner, 1947).

The problem arises as to the precise meaning of the concepts central and peripheral and their status as possible predictors of other phenomena. While it is clear that Warm–Cold is quite different in its effects on the particular check list used than is Polite-Blunt, it is not clear how one would predict these differential effects. In brief, what are the rules for determining on an a priori basis which traits will be

[1] I am indebted to Charles W. Lynch, Vivian Wilson, and Iris Keim for aid in collecting the data, and to several of my colleagues at Harvard University, where the paper was written, and at the University of Pennsylvania, where the investigation was planned and the data collected, for invaluable critical comments. I am grateful to the Laboratory of Social Relations at Harvard University for financial support of the concluding stages of the investigation. I am also indebted to the Department of Psychology at Brandeis University for permitting me to obtain some subjects there.

central and which traits will be peripheral?

Close examination of Asch's interpretations of his results reveals that no such rules are supplied. Indeed, it appears that an essential postulate of Asch's formulation is the unpredictability of the final impression from any prior knowledge of the denotations and connotations of the elements of the stimulus list, individually or in interaction. Thus, he wrote: ". . . the qualities we note in a person derive their content in large part from their lawful relation to one another and their interaction constitutes the unitary impression. According to this assumption, the qualities are seen in their mutual relation, in their place within the whole impression" (Asch, 1952, p. 208). Although this would seem to imply some concept of algebraic interaction between the discrete traits read to the *S*s, Asch rejected such an ideal explicitly. He wrote:

> It is important to note that this formulation [the interaction hypothesis] is in a fundamental regard different from [the dynamic-structural formulation]. The latter proposition asserts that each trait is seen to stand in a particular relation to the other as part of a complete unit. The entire view possesses the formal properties of a structure, the form of which cannot be derived from the summation of the individual relations (Asch, 1946, p. 286).

Both in his 1946 and 1952 discussions, Asch contrasted his own formulation with what he conceived of as an "elementaristic" view. Such a theory, according to Asch, would hold that "Impression = a + b + c + d + e . . . ." While it seems clear in retrospect that this formulation was used as a kind of straw man against which to argue (it also provided the basis for several experiments), it seems also to offer some clues as to how to proceed to delineate the content of the concepts of central and peripheral traits.

One may note that the whole tenor of Asch's discussion seems to stem from an analogy with a perceptual model along classical Gestalt lines. Within such a framework analysis of the minute elements of a percept often seems futile. Perhaps this results from the arbitrary limitation of the form of combination of elements to additivity. Attempts to analyze percepts, or, more abstractly, any wholes, in terms of the combination of smaller units by simple addition have of course failed in many areas of psychology. Yet if we simply change the combinative operation from addition to multiplication, or some other form of interaction, analysis becomes more plausible. In any case, since analysis is the *sine qua non* of a predictive science, further attempts seem indicated.

Perhaps also it might prove more fruitful to view the impressions in terms of concept formation rather than along perceptual lines. From this point of view the essential question may be formulated as follows: what effects do the amount and types of information supplied to an *S* have on the concept formed. If the information is in the form of trait names said to be characteristic of a single person, what kind of impression will be formed and what are its determinants? It seems clear that in order to predict the effects of various kinds of information on the concepts formed, one would have to know something about the relationships obtaining between the various items of information supplied to an *S* as well as between those items and the matters about which concepts are to be formed.

A strong indication that some effects can be predicted was seen in the study by Bruner, Shapiro, and Tagiuri (1958). They showed that a knowledge of the kinds of inferences drawn by *S*s from single trait-names, e.g.,

Intelligent, Considerate, yields an accurate prediction of the kinds of inferences drawn from combinations of these trait-names. However, their results are not directly applicable to Asch's situation since their procedure was quite different. They asked their *S*s for abstract inferences about words, rather than about specific persons. Furthermore, their computational procedures yield results which may be peculiarly dependent on their particular sample, and, in any case, do not seem to be directly applicable to Asch's situation. For example, they report that "50% or more" of their *S*s infer Aggressive from Inconsiderate (Bruner, Shapiro, & Tagiuri, 1958, Table 1, p. 281), but there is no information as to the exact number who do so, nor as to the statistical significance of this individual result. At the same time, the fact of "50% or more" is an important element in their scheme in predicting, for example, the inference of Aggressive from a combination of Inconsiderate and Intelligent. If the actual result were close to 50%, it might easily be less than 50% in another sample, and thus lead to another prediction.

Nevertheless, the study by Bruner, Shapiro, and Tagiuri adumbrates the way in which Asch's results might be predictable. Suppose we knew the intercorrelations among all the traits used by Asch. If we assume that the ratings made by *S*s on the check list depend on the intercorrelations existing between the individual items in the stimulus list and the individual items in the check list, then the ratings ought to be predictable. In Asch's formulation, no provision is made for utilizing prior information about the intercorrelations.

The present paper, then, will report tests of the hypothesis that, in the Asch-type situation, *S*s' ratings of the traits on the check list are a function of the intercorrelations existing between the traits in the stimulus list and those in the check list.

The steps involved in these tests were:

1. Intercorrelations among most of the traits used by Asch were determined.
2. These were applied to the results reported by Asch (1946) and by Mensh and Wishner (1947) by comparing the magnitudes of correlations (e.g., between Warm–Cold and Generous–Ungenerous) with the magnitudes of differences in ratings between groups (e.g., between the Warm and Cold groups in their ratings of Generous–Ungenerous on the check list).
3. New stimulus lists and check lists were constructed to test the hypothesis more directly.
4. Some of Asch's minor results were reanalyzed in the light of these experiments.[2]

PROCEDURES AND RESULTS

Analysis of the effects of the Warm–Cold variation

The first task was to discover as precisely as possible to what extent some of the traits used by Asch were intercorrelated when ratings of actual persons were made. An immediate problem arises in this connection. The information desired is addressed to the question: how do *S*s actually combine traits in rating other real persons? If only one other person is rated, the particular combination of traits characteristic of that person may be unrepresentative of the population of ratees. It would be desirable to obtain ratings from a representative group of raters on a representative group of ratees, but the sampling problems of this procedure made it unfeasible. On the other hand, the procedure used by Bruner, Shapiro, and Tagiuri (1958),

[2] Asch actually reported the results of some 10 experiments. Not all can be discussed in this paper. Those selected for discussion seem the most crucial for the analysis offered.

TABLE 1

LIST OF PERSONALITY TRAITS STUDIED

Trait No.		Trait No.	
01	Clumsy–Skillful	28	Self-centered–Altruistic
02	Ungenerous–Generous	29	Industrious–Lazy
03	Witty–Dull	30	Fearless–Fearful
04	Inactive–Active	31	Inflexible–Flexible
05	Dominant–Submissive	32	Restrained–Talkative
06	Scrupulous–Unscrupulous	33	Humorous–Humorless
07	Irritable–Good natured	34	Practical–Unpractical
08	Conscientious–Irresponsible	35	Strong–Weak
09	Foolish–Shrewd	36	Humane–Ruthless
10	Warm–Cold	37	Unjust–Just
11	Sociable–Unsociable	38	Unreliable–Reliable
12	Unhappy–Happy	39	Ambitious–Unambitious
13	Determined–Indecisive	40	Vain–Modest
14	Critical–Tolerant	41	Shallow–Profound
15	Insincere–Sincere	42	Stubborn–Compliant
16	Unattractive–Good-looking	43	Persistent–Wavering
17	Unbending–Yielding	44	Aggressive–Unaggressive
18	Serious–Frivolous	45	Imaginative–Unimaginative
19	Unintelligent–Intelligent	46	Calm–Agitated
20	Unstable–Stable	47	Sensitive–Insensitive
21	Unhelpful–Helpful	48	Popular–Unpopular
22	Cautious–Impulsive	49	Persuasive–Unpersuasive
23	Kind–Cruel	50	Unenvious–Envious
24	Blunt–Polite	51	Evasive–Direct
25	Slow–Quick	52	Stupid–Wise
26	Important–Insignificant	53	Dishonest–Honest
27	Hard–Soft		

mentioned above, seems to depend too much on linguistic stereotypes, which may be relatively unrelated to how these traits are actually combined in rating others well-known to the ratees; moreover, the method does not yield a numerical estimate of the strength of relationship between traits.

It was decided, therefore, to have different groups of *Ss* rate different individuals. The statistical problems created by this procedure will be discussed as they arise.

Fifty-three traits of those used by Asch were selected for study, as shown in Table 1. Some initial problems were encountered in the choice of opposites or antonyms for the extreme poles of each scale, for a few of Asch's contrasts seemed too subtle to allow the raters to proceed without excessive explanation. Thus, for example, Asch's Wise–Shrewd was expanded into Foolish–Shrewd (see 09 in Table 1), on the one hand, and Stupid–Wise on the other (52 in Table 1).[3] These traits were arranged 8 to a sheet on a 6 point scale, represented graphically by a line at the top of each page with the 6 points marked off, as shown in Fig. 1. In addition, each trait was broken down verbally into 6 concrete categories; e.g., a rating of 1 was assigned to "very stubborn," a rating of 2 to "moderately stubborn," and so

[3] These are matters of judgement, of course. As it turns out, it would have been wiser not to arrange the series in terms of polar opposites at all, for what we judge to be opposites on grammatical or linguistic grounds may not function as opposites psychologically, as will be seen in some of the results below.

1	2	3	4	5	6
very	moderately	somewhat	somewhat	moderately	very

FIG. 1. The graphic scale presented to the raters.

on to a rating of 6 assigned to "very compliant." The traits were initially arranged in random order, and the sheets were stapled together in 7 different orders so that each was in each position (1st, 2nd, etc.) an equal number of times, approximately.

The *S*s (raters) were 214 students in 10 laboratory sections of an introductory course in psychology. They were told that they were participating in an experiment on "how people perceive others," and were asked to rate their instructors on each of the 53 traits.[4] The questionnaires were anonymous and the students were assured both by their instructors and by *E* that their ratings would not affect the status of the instructors. Altogether, 8 different instructors were rated.

The data were cast into 2×2 contingency tables, with the split as close to the median of ratings on each trait as feasible. Phi coefficients were computed, and these were transformed into estimates of r by the method recommended by Camp (Edwards, 1946, pp. 120–121).[5]

The estimates of r yielded by this procedure represent weighted means of the mean covariance within groups and the covariance between group means (see Gassner & Mosteller, 1959). For our purposes, they will be treated as the best estimates of the correlation between any two traits.

Table 2 shows the estimated rs between the items in Asch's stimulus list and those in his check list. The items in the check list were identical with those used in this study, with the following exceptions: Asch's Shrewd–Wise was omitted from this aspect of the study because it had been changed so substantially by expanding it to Stupid–Wise and Foolish–Shrewd in the rating scales; Persistent–Unstable was changed to Persistent–Wavering; Imaginative–Hard-headed was changed to Imaginative–Unimaginative. The check list items in Table 2 are arranged in the order of the magnitude of their differences between the Warm and Cold groups in the Asch (1946) and Mensh and Wishner (1947) studies combined.

Examination of Table 2 indicates that Warm–Cold correlates most highly with those items in the check list which showed the greatest differences between the Warm and Cold groups. This can be expressed quantitatively in terms of rho = .62 ($P < .01$) between the absolute magnitude of rs between Warm–Cold and the check list items on the one hand, and the magnitude of the differences in those items between the Warm and Cold groups in the Asch and Mensh and Wishner studies, on the other. It is important to remember that the two results being correlated were obtained in two quite different kinds of experimental situations. Thus, this result is not self-evident, as might be inferred superficially. It indicates that one can predict results in the Asch-type situation from a *prior* independ-

[4] Several other ratings for other research purposes were taken at the same time.

[5] These computations were made possible by the University of Pennsylvania Computer Center and by the National Science Foundation. I am indebted to Peter Ingerman for programming these computations, and to IBM for making time available on their machines for preliminary trials. The IBM center at the Wharton School and its personnel were most helpful in the initial punching and sorting of cards.

ent knowledge of the relationships obtaining between the traits to be rated and the stimulus traits. If one stimulus is to be varied, and if it is relatively uncorrelated with the other stimuli, as is true in the Warm–Cold experiment, the effects of the variation will be a function of the correlation coefficients between that stimulus and the responses to be made; the correlations can be obtained independently of the particular experimental situation for which a prediction is desired. Thus, the main hypothesis of this study receives support.

Varying Unintelligent–Intelligent

Another interesting aspect of the results of Table 2 is the fact that the magnitudes of the differences between the Warm and Cold groups are *inversely* related to the magnitudes of *r*s between the other six items in the stimulus list and the items in the check list. This means that those items on the check list which did not change as a function of Warm–Cold tend to be more highly related to the nonWarm–Cold items in the stimulus list than those items which did change.

TABLE 2

ESTIMATES OF *r** AMONG TRAITS USED BY ASCH

(N = 214)

(Decimals omitted)

	Trait No.	10	19	01	29	13	34	22	24
Stimulus List	19 Unintelligent	−07							−13
	01 Clumsy	−10	31						04
	29 Industrious	26	−35	−44					−25
	13 Determined	34	−38	−47	34				−01
	34 Practical	25	−33	−35	53	23			−02
	22 Cautious	−00	12	07	09	−02	10		−25
Check List[a]	02 Ungenerous	−33	04	−07	−12	−10	−09	−15	48
	07 Irritable	−57	01	18	−18	−20	−24	07	42
	33 Humorous	24	−16	−12	−04	38	01	−24	36
	11 Sociable	70	00	−07	26	30	16	−11	−23
	48 Popular	50	−33	−26	24	35	35	01	−10
	28 Self-centered	−30	14	−03	−13	−01	−20	−08	45
	12 Unhappy	−54	21	07	−36	−35	−22	08	20
	36 Humane	34	−06	00	28	−12	27	29	−63
	45 Imaginative	48	−17	−17	24	43	18	−31	05
	32 Restrained	−13	15	03	04	−14	08	35	−33
	16 Unattractive	−10	36	−04	−23	−08	−05	−15	19
	38 Unreliable	−28	31	34	−41	−15	−44	−15	34
	35 Strong	07	−28	−10	14	39	31	01	08
	53 Dishonest	−43	28	06	−30	−14	−28	−08	36
	26 Important	17	−50	−28	30	35	23	−18	−12
	18 Serious	02	−09	−34	27	18	25	24	−17
	43 Persistent	18	−30	−28	20	60	12	16	12
	Rho[b]	62	−.56	−.29	−.40	−.20	−.27	−.21	.43
	P	<.01	<.05	>.10	<.10	>.10	>.10	>.10	<.05[c]

* Significance of any result was actually established on the basis of Chi square. Assuming a mean value of .60 for Camp's constant (see Edwards, 1946, pp. 120–121), probably an overconservative estimate, *r*'s significant at P = .05, .01, and .001 are .22, .30, and .38, respectively.

[a] Arranged in order of magnitude of difference between "warm" and "cold" groups, Asch (1946) and Mensh and Wishner (1947) experiments combined. See text for explanation of omissions and changes.

[b] Between magnitude of differences between groups and magnitude of estimated *r*.

[c] One-tailed test.

TABLE 3

PER CENT *Ss* CHECKING EACH TRAIT, CHI SQUARE, AND ESTIMATES OF *r* WITH UNINTELLIGENT-INTELLIGENT

(Listed in order of magnitude of *r*)

Trait No.	*r*	Unintelligent $N = 116$–118 %	Intelligent $N = 124$–126 %	Chi Square	P $(df = 1)$
52 Stupid	.68	60	2	91.02	<.001
09 Foolish	.61	35	1	41.86	<.001
41 Shallow	.54	87	17	118.41	<.001
26 Important	−.50	33	92	89.60	<.001
39 Ambitious	−.36	90	97	3.94	<.05>.02
14 Critical	.05	43	58	4.74	<.05>.02
02 Ungenerous	.05	23	34	3.19	<.10>.05
31 Inflexible	−.03	62	32	20.99	<.001
23 Kind	−.03	85	83	.06	>.80
07 Irritable	.02	22	28	1.09	>.20
11 Sociable	.00	74	86	4.50	<.05>.02

This is particularly evident in the case of Intelligent, which suggests a further test of the proposed alternative interpretation of the data.

If the explanation in terms of the independently determined correlations between the traits in the stimulus list and in the check list is correct, then varying Unintelligent–Intelligent should produce different patterns in check list markings between a group hearing Intelligent and a group hearing Unintelligent, but the differences should be on different traits in the check list than is produced by varying Warm–Cold. If this is so, of course, it would mean that Warm–Cold is not the only central trait in the stimulus list, in Asch's terms. Indeed, it is conceivable that we could make all items in a stimulus list "central" by appropriate manipulations of the check list, in contrast to Asch's method, which consists of varying the stimulus list.

Asch's theory does not yield a direct prediction of the effects of varying Intelligent, except that there would be an embarrassment of riches in "central" traits if the effect were as large as that for Warm–Cold. However, varying the position of an item in the stimulus list ought to make a difference for any Gestalt-like theory of structure. No such difference would be predicted on the basis of interrelations among elements, so long as the stimulus list was not too long (to avoid serial position effects in memory), and provided that the variation did not produce internally inconsistent information.

In order to test the effects of position and of varying another trait in the same stimulus list, the following experiment was performed. The trait-names read to the *Ss* were: Skillful–Industrious–Determined–Practical–Cautious. Intelligent was inserted into the 1st, 3rd, and 6th position, respectively, for three groups, and likewise, Unintelligent for three other groups. The procedure was identical to that used in previous studies (Asch, 1946; Mensh & Wishner, 1947), except that the intermediate step of writing an impression between hearing the stimulus list and marking the check list was eliminated. However, there were 2 readings of the list with a pause in between, during which the *Ss* were instructed to form an impression of the

person; they were then asked to mark the check list in accordance with their impressions. A check list was constructed of all items having correlations of at least .35, and of all items having correlations of .10 or less, with Unintelligent–Intelligent. It was predicted that the former would show greater differences between the Intelligent and Unintelligent groups than the latter. The *S*s were students in an introductory psychology course, with approximately equal numbers of males and females.

The data were examined first for effects of position by means of chi-square tests. In the case of no item in the check list was there a significant difference among the 3 groups who had heard Intelligent, nor were there any significant differences among the three groups who heard Unintelligent. In brief, there was no evidence that the position of the trait varied had any effect on the final check list scores.

The data of the Intelligent and Unintelligent groups, respectively, were therefore combined, and the results are shown in Table 3. The check list traits are listed in the order of the magnitude of their correlations with Unintelligent–Intelligent. It can be seen that significant differences between the groups occur in all the instances where Unintelligent–Intelligent is significantly correlated with the item concerned. At the same time, there are also significant differences in three of the six items uncorrelated with Unintelligent–Intelligent. A direct test of the prediction was made by computing Kendall's tau between the magnitudes of the chi squares of the differences and the two classes of correlations (high and low). This was significant, with tau = .59 ($P < .05$). Thus, the hypothesis that differences in check list ratings may be attributed to the relationships (determined on independent grounds) between those items and the trait being varied is supported.

With respect to the three significant differences found in the items uncorrelated with Unintelligent–Intelligent, examination of the intercorrelations among the stimulus traits shows that, unlike Warm–Cold, Unintelligent–Intelligent is significantly intercorrelated with four of the other five items used in this study, as shown in Table 4. Thus, a certain amount of contradictory information was introduced for the Unintelligent group. As might have been expected on the basis of these intercorrelations, those items of the check list significantly related to Intelligent also tend to be correlated with the other traits in the stimulus list. The result may be that the effect of Unintelligent in the stimulus list is decreased from what it might have been had the same items in the check list been unrelated generally to the stimulus list, as was seen in the Warm–Cold experiment. Ambitious–Unambitious is a case in point. Its correlation with Unintelligent–Intelligent is −.36; its correlations with Industrious–Lazy, Determined–Indecisive, and Practical–Unpractical are .45, −.47, and .62 (Table 4), respectively.[6] It seems quite possible, therefore, that the presence of Industrious, Determined, and Practical in the stimulus list would tend to decrease the effect of Unintelligent, although the latter still makes for a statistically significant difference from the Intelligent group.

Similar effects of the patterns of intercorrelations can be seen in the other significant differences. Note, for example, the relatively weak re-

[6] These *r*s are not unimpressive in the light of the limitations imposed in the computation of phi from a 2×2 table, and in view of the assumption that $r < .80$ involved in using Camp's estimate.

TABLE 4

ESTIMATES OF r AMONG STIMULUS AND CHECK LIST TRAITS
UNINTELLIGENT-INTELLIGENT EXPERIMENT

(N = 214)
(Decimals omitted)

Trait No.	01 Clumsy	29 Industrious	13 Determined	34 Practical	22 Cautious
52 Stupid	55	−42	−47	−15	05
09 Foolish	28	−40	−58	−27	03
41 Shallow	26	−26	−19	−25	−09
26 Important	−29	31	36	24	−18
39 Ambitious	−36	45	47	62	13
14 Critical	01	−14	−07	−23	−34
02 Ungenerous	−07	−11	−10	−10	−16
31 Inflexible	−01	−02	03	04	08
23 Kind	−06	23	01	27	17
07 Irritable	18	−18	−18	−24	08
11 Sociable	−07	26	31	16	−11

lationships between Shallow–Profound and all of the items in the stimulus list, with the exception of Unintelligent–Intelligent. The fact that the Unintelligent and Intelligent groups are almost exactly complementary (87% to 17%, Table 3) or opposed in their ratings of Shallow, seems precisely congruent with the pattern of intercorrelations. On the other hand, note the relatively weak effects of Unintelligent on Stupid (60%) and Foolish (35%). Since these are definitions of Unintelligent, at least in some senses, closer to 100% of this group might have been expected to rate the person as Stupid and Foolish respectively. Again, the pattern of intercorrelations hints at a possible explanation. Stupid–Wise and Foolish–Shrewd are moderately related to the other items in the stimulus list. The effect of Unintelligent may be modified considerably therefore, by the presence of Skillful, Industrious, Determined, and Practical in the stimulus list. Perhaps not altogether accidentally, the effect of Unintelligent on Stupid and Foolish seems about midway between its effect on Shallow, which is only weakly related to the other items in the stimulus list, and its effect on Ambitious (see Table 3) which is strongly related to the other items, but only weakly to Unintelligent. In order to take into account the intercorrelations between the *rest* of the stimulus list and the check list, tau was computed on the basis of three classes of correlations: (*a*) items having high correlations with Unintelligent–Intelligent and low correlations with the remainder of the stimulus list, (*b*) items having high correlations with Unintelligent–Intelligent and at least two correlations of .30 or above with the remainder of the stimulus list, (*c*) items having low correlations with Unintelligent–Intelligent. These were related to magnitude of chi square, with the result: tau = .65 ($P < .01$), which indicates the strength of the prediction when more of the relevant data is included in its test.

In summary, the results to this point seem to show:

1. Asch's original results in the Warm–Cold experiment are predictable on the basis of the intercorrela-

tions between Warm–Cold and the individual items in his check list.

2. Varying Unintelligent–Intelligent produces effects on a check list predictable from a knowledge of the intercorrelations between the items in the stimulus list and those in the check list.

3. The ordinal position of Intelligent and Unintelligent in the stimulus list had no effect on the final ratings.

Varying Blunt–Polite

In an attempt to demonstrate the differences between central and peripheral traits, Asch varied Blunt–Polite in a stimulus list otherwise identical with that of the Warm–Cold experiment, and with an identical check list. Since the differences between the Warm and Cold groups were clearly greater than the differences between the Blur and Polite groups, Asch concluded that Blunt–Polite should be conceptualized as a peripheral trait within the context of the stimulus list involved. From the point of view of the present formulation, the results should be predictable on the basis of the intercorrelations among the stimuli and between the stimulus list and the check list.

Table 2 reveals that Blunt–Polite is generally uncorrelated with the other items in the stimulus list, but is correlated significantly with some of the items in the check list. Following the procedure in the initial analysis of the Warm–Cold variation, rho was computed between the magnitude of the estimated *r*s and the magnitude of the differences between the Blunt and Polite groups (for these values, see Asch, 1946, Table 2, p. 263). Table 2 indicates that rho = .43 ($P < .05$) with a one-tailed test. Thus, items correlated with Blunt–Polite show greater differences between the groups than items not correlated. This is particularly impressive in the light of the generally small differences between the groups, probably unreliable in some cases.

As in the case of Unintelligent–Intelligent, it seemed desirable to perform a new experiment, keeping the stimulus list constant, but with a new check list, composed of items with high and low correlations, respectively, with Blunt–Polite. This constitutes a more direct test of the alternative hypotheses, for Asch's theory rests on the context in which a trait is found among stimuli. Since the stimulus list is identical with that used by Asch, the central-peripheral theory should again predict relatively little difference between the Polite and Blunt groups. On the other hand, utilizing the formulation proposed here, differences between the groups should appear, as a function of the degree of correlation between the check list and Blunt–Polite, modified by the nature of the intercorrelations between the check list and the rest of the stimulus list.

Consequently, as in the case of Unintelligent–Intelligent, a new check list was constructed, composed of items having the highest and lowest correlations with Blunt–Polite, as shown in Table 5. Unfortunately, only 4 items could be found which were consistently uncorrelated[7] with Blunt–Polite, a result which may affect adversely the chances of obtaining significant differences between the two classes of correlations, and which is surprising in the light of its previous classification as a peripheral trait. The stimulus list was identical with that used by Asch: Intelligent–Skillful–Industrious–

[7] The original correlations had been broken down into sex groupings for raters and ratees. Thus, there were actually 5 different matrices of *r*s. Some items were rejected even when they met the stated criteria if there was no consistency in their *r*s from group to group.

TABLE 5

PER CENT *Ss* CHECKING EACH TRAIT, CHI SQUARE AND ESTIMATED *r*'s BETWEEN CHECK LIST AND BLUNT-POLITE

Trait No.	*r*	Blunt $N = 59$–61 %	Polite $N = 47$–50 %	Chi Square	P $(df = 1)$
08 Conscientious	−.44	100	100	—	>.50
35 Strong	.08	93	96	.03	>.50
07 Irritable	.42	55	25	8.68	<.01
21 Unhelpful	.52	28	4	9.16	<.01
17 Unbending	.53	87	65	6.03	<.02
28 Self-centered	.45	82	53	9.32	<.01
46 Calm	−.43	77	86	1.42	>.10
49 Persuasive	.06	87	74	2.19	>.10
23 Kind	−.72	58	85	7.77	<.01
06 Scrupulous	−.10	64	84	4.39	<.05
36 Humane	−.63	80	88	1.07	>.10
14 Critical	.71	82	42	17.26	<.001
48 Popular	−.10	57	84	7.61	<.01
37 Unjust	.49	13	8	.27	>.50
27 Hard	.55	95	61	17.41	<.001
47 Sensitive	−.37	49	65	2.25	>.10
15 Insincere	.52	11	12	.03	>.50

Blunt or Polite–Determined–Practical–Cautious; one group hearing Blunt and the other Polite.

The results of the ratings, as well as the estimated *r* between each item on the check list and Blunt–Polite, are shown in Table 5. On 9 of the 17 items, the differences between the Blunt and Polite groups are significant. This would seem to make Asch's explanation of his results untenable, inasmuch as there are about as many significant differences as are produced by Warm–Cold in a check list of similar length. Moreover, it must be remembered that 4 items in the present list were deliberately chosen because of their low correlation with Blunt–Polite. Asch gives no information as to the basis for the choice of the items to be rated.

As in the previous experiment, Kendall's tau was first computed on the basis of 2 classes of correlations: tau = .14 ($P > .10$). Seven of the significant differences are in items having high correlations with Blunt–Polite and 2 are in items having low correlations. The differences in all 13 highly correlated items are in the predicted direction. A breakdown of the correlations into 3 classes for predictive purposes, as in the previous experiment, yields tau = .27 ($P < .10$) with the magnitude of chi square. In all, then, there would seem to be a tendency for the hypothesis to be supported.

Table 6 shows the intercorrelations between the stimulus list, exclusive of Blunt–Polite, and the check list. An analysis of these in a similar vein to that made in the Unintelligent–Intelligent experiment, indicates that high correlations with the items in the stimulus list which are constant from group to group may have prevented more substantial differences from appearing in the cases of Conscientious–Irresponsible, Unjust–Just, and Insincere–Sincere. In general, however, it appears that the results of this experiment are not as clearly supportive of the elementaristic hypothesis as the

previous ones. On the other hand, Asch's formulation is quite incapable of dealing with the results. It may be that many complicated interactions among terms need to be taken into account, and in the following experiment, an attempt was made to simplify the internal relationships among the traits in the stimulus list and the check list.

Variations in Simplified Lists

The results reported to this point made it clear that complicated interactions occur when the trait varied is correlated with the other items in the stimulus list, and when the other constant items in the stimulus list are correlated with traits in the check list. New lists were therefore constructed in which these complications were eliminated.

The stimulus list was: Scrupulous–Cautious–Good-looking–Humane or Ruthless–Flexible–Serious–Fearless, one group hearing Humane and the other Ruthless. As Table 7 shows, these traits are generally uncorrelated with each other. With respect to the check list, Humane–Ruthless is highly correlated with six items and uncorrelated with the other six. The other six traits in the stimulus list are generally uncorrelated with the check list. Thus, we have a situation in which there should be no suppressor effect on predicted differences on the check list between the Humane and Ruthless groups, since there are no significant correlations between the six constant traits on the stimulus list and the crucial traits on the check list.

Table 8 shows the results of this experiment. As predicted, the six traits correlated with Humane–Ruthless show significant differences between the groups; no other significant differences appear.

A further variation of this experiment was done in order to test the effects of context at the limit. Each trait on the stimulus list was converted

TABLE 6

ESTIMATES OF *r* BETWEEN STIMULUS LIST AND CHECK LIST: BLUNT-POLITE EXPERIMENT

(N = 214)
(Decimals omitted)

Trait No.	19 Unintelligent	01 Clumsy	29 Industrious	13 Determined	34 Practical	22 Cautious
08 Conscientious	−14	−25	45	25	39	30
35 Strong	−28	−10	14	39	31	01
07 Irritable	01	18	−18	−20	−24	07
21 Unhelpful	13	11	−21	−25	−23	−06
17 Unbending	−13	−03	05	16	−03	−04
28 Self-centered	14	−03	−13	−01	−20	−08
46 Calm	05	−06	21	−08	20	28
49 Persuasive	−19	−33	27	62	31	−01
23 Kind	−03	−06	23	01	27	17
06 Scrupulous	−20	−26	10	17	32	18
36 Humane	−06	00	28	−12	27	29
14 Critical	05	01	−14	−07	−23	−34
48 Popular	−33	−26	24	35	35	01
37 Unjust	46	09	−24	−17	−34	−04
27 Hard	−14	−31	12	43	05	−18
47 Sensitive	02	−07	−03	13	22	09
15 Insincere	27	19	−36	−20	−35	−16

TABLE 7

ESTIMATES OF r AMONG STIMULUS AND CHECK LIST TRAITS IN ORDER (RANDOM) PRESENTED: HUMANE-RUTHLESS EXPERIMENT

$N = 214$
(Decimals omitted)

	Trait No.	06	22	16	36	31	18	30
Stimulus List	06 Scrupulous							
	22 Cautious	18						
	16 Unattractive	07	−15					
	36 Humane	13	29	−18				
	31 Inflexible	−10	−08	02	−16			
	18 Serious	11	24	−17	10	12		
	30 Fearless	06	11	−08	08	−05	−00	
Check List	26 Important	08	−18	−24	02	−05	−03	27
	37 Unjust	−24	−04	14	−62	02	−04	−29
	24 Blunt	−10	−25	19	−63	12	−17	−05
	28 Self-centered	−01	−08	12	−71	29	−03	−07
	35 Strong	03	01	−30	−05	05	22	16
	07 Irritable	−21	07	−01	−53	16	07	−00
	51 Evasive	−12	19	08	04	05	05	−29
	41 Shallow	−01	−09	25	−03	−07	−11	−20
	02 Ungenerous	−11	−15	−12	−51	17	13	−05
	04 Inactive	−20	−03	−16	−05	10	−13	−28
	23 Kind	02	17	−08	79	−12	−09	00
	25 Slow	−13	21	04	−03	12	04	−25

into its opposite, the prediction being that the pattern of differences between the Humane and Ruthless groups should be the same as in the previous experiment, although the absolute impressions formed might be quite different from those in the previous experiment. Thus, the stimulus list was: Unscrupulous–Impulsive–Unattractive–Humane or Ruthless–Inflexible–Frivolous–Fearful. The check list was identical with the previous experiment.

The results are shown in Table 8. Of the six predicted differences, five are significant at ($P < .01$) and one (Blunt–Polite) at ($P < .10$). Of the six traits predicted not to differ between the groups, two are significant at ($P < .05$) and one at ($P < .10$). Thus, the prediction is clearly supported. The inversion of the context in which Humane or Ruthless was imbedded has had only a minor effect on the differences in ratings between the two groups. Check list ratings, in the main, continue to be a function of the correlation of the individual traits rated with the crucial trait in the stimulus list.

GENERAL DISCUSSION

The previous findings would seem to point to a simple and clear method for specifying the nature of central and peripheral traits. A trait is central for those traits correlated with it and peripheral for those traits uncorrelated with it. It will have strong effects on impressions if raters are asked to infer the former and weak effects if the latter are rated.

This would seem to constitute a specific implementation of a structural point of view, an approach to Asch's implicit position. The latter's emphasis

on context is of course extremely important, and is not in any way disturbed by the present findings and formulation; it is only defined operationally. Obviously, *S* forms an impression within certain contexts, i.e., as a function of various prior and experimentally induced sets. For example, *S* is told that the characteristics he is about to hear refer to an *adult, male person,* and not to a female, baby, animal, or machine. Each of the words used can have reference to a wide variety of things (Asch, 1958). By specifying an adult, male, *E* immediately limits *S*'s possible inferences. Each succeeding item of information, in this case the trait names, further limits and specifies the picture *S* forms. We must be sure, of course, that we are indeed adding information and not just redundancy. In language, however, redundancy is never complete, and so we need to know the specific implications of each term *within the context or set already established* by the initial instructions and by the previous terms. The results reported here, taken as a whole, indicate that subsequent ratings of individual traits can be attributed to the specific intercorrelations between the stimuli and the traits to be rated. In lists of seven or less items, order seems unimportant, unless there are high and inverse correlations among some of the stimuli (Asch, 1946, pp. 270–273).

One of Asch's main arguments for his thesis has not yet been examined. This is that *S*s form "unitary," internally consistent impressions, which is in turn consistent with a structural (Gestalt?) theory. It is implied that an "elementaristic" theory would predict something else, presumably a fragmented, discontinuous impression. Part of the evidence marshalled in support of the former theory consists of the fact that *S*s write connected, sensible passages about a person after hearing a series of discrete traits alleged to be characteristic of him. Another type of evidence consists of Asch's demonstration that *S*s may experience difficulty in reconciling certain kinds of internally inconsistent information

TABLE 8

PER CENT *S*s CHECKING EACH TRAIT AND CHI SQUARE: HUMANE-RUTHLESS IN TWO OPPOSED CONTEXTS

Context	Trait No.	Scrupulous, Cautious, Good looking, Flexible, Serious, Fearless				Unscrupulous, Impulsive, Unattractive, Inflexible, Frivolous, Fearful			
		Humane $N = 31–32$ %	Ruthless $N = 25–27$ %	Chi Square	P ($df = 1$)	Humane $N = 39–41$ %	Ruthless $N = 34–36$ %	Chi Square	P ($df = 1$)
High Correlations with Humane-Ruthless	23 Kind	87	19	24.55	<.001	73	3	36.58	<.001
	28 Self-centered	34	88	15.14	<.001	73	97	6.68	<.01
	24 Blunt	23	52	4.16	<.05	75	92	2.63	<.10
	37 Unjust	3	54	16.69	<.001	64	94	8.52	<.01
	07 Irritable	22	58	6.37	<.02	71	97	7.74	<.01
	02 Ungenerous	19	73	15.12	<.001	45	83	10.37	<.01
Low Correlations with Humane-Ruthless	35 Strong	91	93	.07	—	29	36	.15	—
	04 Inactive	6	0	.03	—	20	11	.48	—
	51 Evasive	13	11	.04	—	66	39	4.56	<.05
	41 Shallow	12	24	.60	—	76	89	3.44	<.10
	25 Slow	37	15	2.49	<.20	22	14	.38	—
	26 Important	94	100	.33	—	33	59	4.14	<.05

if they are led to believe initially that the contradictory information refers to two separate people. Thus, Asch asked a group of *S*s to write an impression of a person who is Intelligent–Industrious–Impulsive; he then asked the same group to write another impression of another person who is Critical–Stubborn–Envious. Finally, he informed the *S*s that the six terms really referred to one person and asked them to reconcile their impressions. These *S*s complained of much more difficulty than did those in another group who had been informed initially that the terms referred to one person. (Asch, 1946, pp. 273–275). However, one *S* is quoted rather revealingly as foldows: "As I have set down the impressions, one is exactly the opposite of the other. But I can fit the six characteristics to one person" (Asch, 1946, p. 275). This *S*'s remark indicates why this point cannot be assigned much importance as a bone of contention. No theory would argue that *S*s cannot arrive at superordinate concepts from discrete elements. Several experiments have shown that *S*s are capable of reconciling even internally inconsistent information if they are asked to do so (Haire & Grunes, 1950; Pepitone & Hayden, 1955; Bruner, Shapiro, & Tagiuri, 1958). Indeed, this is obvious from everyday categorizing behavior.

The issue of redundancy, mentioned above, in itself may constitute an interesting problem for research on how adjectives combine. Cliff (1959) has shown that adverbs and adjectives of certain types combine multiplicatively. In addition, he suggests that repeated adverbs, e.g., "very, very," combine according to a power function (p. 42). What would be the rule for a set of redundant adjectives? Indeed, the degree of redundancy might be specified in terms of the intercorrelations among them.

Finally, an interesting implication for research in personality trait scaling and for related semantic research (Osgood, 1958; Hays, 1958) should be pointed out. It is a common practice for researchers to construct dimensions or continua, with antonyms arranged as polar opposites, as was done in this study, e.g., Warm–Cold, Skillful–Clumsy, etc. The results, in several instances (see section on Unintelligent–Intelligent), indicate that grammatical antonyms do not necessarily correspond to psychological opopposites. Unintelligent is not only an antonym of Intelligent; it seems to have positive implications of its own. For research purposes, therefore, one ought to avoid the assumption of phenomenal opposition in the case of antonyms. If traits are to be measured, it would seem more meaningful psychologically to construct scales around each trait separately, rather than combining it with its antonym in a single scale. Thus, we might measure separately the degree of warmth in one instance and the degree of coldness separately in another (Lemann & Solomon, 1952, pp. 11–14). With the numerical values of easily usable adverbs now supplied by Cliff (1959), the power of such ratings should be increased substantially in various researches on personality.

One hesitates to go further with the implications of the foregoing research, since these arise only in retrospect and were not adequately conceptualized when this study was begun. Nevertheless, it would seem to be in the direction indicated that the most fruitful applications of the techniques and formulations proposed in this paper can be made.

SUMMARY AND CONCLUSIONS

Asch's interpretation of his data on impressions of personality as representing a unitary, wholistic result, underivable from a knowledge of the connotations of the individual elements and their interactions in the information input, does not yield predictions with respect to new stimulus and response lists. It was shown that the seemingly large differences in ratings of a check list between two groups hearing Warm and Cold, respectively, in the context of Intelligent–Skillful–Industrious–Determined–Practical–Cautious, can be predicted from a knowledge of the specific intercorrelations, independently obtained, between each trait to be rated and Warm–Cold. Similarly large differences between groups were obtained by varying Unintelligent–Intelligent and Blunt–Polite within the same stimulus context, when the check list was composed of items known to correlate with each of these on the basis of a prior study. The prediction that items correlated with the trait varied would show greater differences between groups than uncorrelated items was clearly supported in the case of Unintelligent–Intelligent. In the case of Blunt–Polite, the result is less clear ($P < .10$) when the effects of intercorrelations between the remainder of the stimulus list and the check list are taken into account.

When lists were constructed such that (*a*) all items in the stimulus list were uncorrelated with each other, and (*b*) half of the items in the check list were correlated with the trait varied (Humane–Ruthless), and half were uncorrelated with any of the stimulus traits, the results were exactly according to prediction: significant differences between the Humane and Ruthless groups were found in all the correlated traits, and no significant differences were found in the uncorrelated traits. Even when the stimulus traits were converted into their opposites, so that Scrupulous became Unscrupulous, Serious became Frivolous, etc., the pattern of differences between the Humane and Ruthless groups remained the same.

The ordinal position of Intelligent and Unintelligent in a six-item list had no systematic effect on the final ratings.

From these facts, it was concluded that Asch's central and peripheral effects can be predicted on the basis of knowledge of the specific intercorrelations involved. In general, a stimulus trait will have strong effects if the items to be judged are correlated with it, and weak effects if they are uncorrelated.

The general process of handling information input was discussed in relation to Asch's theory and to Cliff's recent work, and some implications for further research were indicated.

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THE MODEL IN THEORY CONSTRUCTION

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The scientific enterprise as here conceived consists of two related but discriminatively different activities. One is the observation of objects and events, both experimentally and less formally. The other involves the use of mathematical and natural linguistic symbols, along with the rules for their manipulation, to represent these sensory experiences, to organize what is observed into some comprehensible order, and by proper symbolic manipulation to arrive at a representation of what has not yet been observed. The commentary that accompanies these latter theoretical undertakings frequently includes the term "model," the meaning of which can, at best, be imperfectly ascertained from the context. It has been claimed, not infrequently, that while some distinct referent can be delineated in physics, the term "model" has lost all semblance of meaning in psychology (e.g., Underwood, 1957, p. 257). Actually, the physical scientist has permitted himself wide latitude in the use of the term "model" and the psychologist has followed suit.

The plan of this paper is to analyze certain meanings and functions of the concept of a model; distinctions made will then be exemplified in some actual theories from contemporary psychology and classical physics. Implications of the properties of models for theory construction will then be examined in a systematic fashion. The consequences of this analysis for a sample of methodological problems currently at issue will be explored.

Two properties of the analysis to follow should be noted. First, although the profusion of ideas referred to by the term model is often interrelated and compounded, it will be necessary for analytic purposes to separate the various meanings and functions into discrete categories. With this exception, the explication of the concept of the model will follow as closely as possible the actual scientific usage. Secondly, while the symbolic form of conveying the ideas of a model may take the form of a word, sentence, diagram, or mathematical calculus, the distinctions to be made concern the meanings of the concept of model and its functional properties within a theoretical system.

Since model has been used interchangeably with or in reference to various parts of a theory, it is necessary to distinguish such theoretical structures, if only crudely. For our present purpose, it will suffice to differentiate among the parts of certain theories: (*a*) the principles, postulates, or hypothetical ideas, including the relations among them; (*b*) the sentences, equations, or theorems, derived therefrom; (*c*) the coordinating definitions relating theoretical terms to the observational sentences. The textual commentary accompanying the type of theory with which we are concerned may not explicitly designate all the parts of such a structure. It is part of the task of methodological analysis to isolate this structure. Finally, it will be useful to distinguish the formal

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theory from the *separate system* which is the model. This meaning of model may refer to, but need not necessarily refer to, what is frequently called the analogy. A model as an order structurally independent of the theory is the prominent notion. Equally important, more than one model generally functions for a theory. The model, consisting of a separate system, brings to bear an external organization of ideas, laws, or relationships upon the hypothetical propositions of a theory or the phenomena it encompasses. This external organization or model contributes to the construction, application, and interpretation of the theory. Precisely how this is accomplished can be clarified by analyzing the meanings and functions of the model concept.

FUNCTIONS OF MODELS

I. Models Providing Modes of Representation

Empirical elements and relationships which constitute the phenomena to be organized by a theory are known to us by the symbolic system or language that designates these data. By introducing a model constituting a separately organized system, we are providing an additional system of representation for the phenomena and a suitable way of speaking about them. An essential characteristic of "modular"[2] representation constitutes the furnishing of *new* ways of regarding or thinking about the empirical objects and events. Attributes and meanings of the model are transferred from their initial context of usage to the new setting. This application of unprecedented modes of representation can be executed on two levels. Objects and events formulated directly from observation are thought about in the new and unusual fashion prescribed by the model.

At another level, a model may provide novel modes for conceiving the hypothetical ideas and postulates of a theory. Consider the conditioning model: applied to perceptual phenomena, it illustrates the first or empirical level of application. If perception is *regarded* as though it were a conditioned response, to some *determinable* degree perceptual behavior should be capable of treatment in accordance with the laws of conditioning: frequency, stimulation interval, etc.; if so, the relationships and language of conditioning may be fruitfully applied. Howes and Solomon's (1951) findings may be so regarded. In this example, some such analogy with conditioning is said to provide an empirical or pretheoretical model (Koch, 1954). In contrast, the fractional anticipatory response mechanism—r_g theory—(Amsel, 1958; Kendler & Levine, 1951; Moltz, 1957; Spence, 1951a, 1951b; etc.) illustrates the second level of representative functioning for the conditioning model. Here, the postulated nonobservable fractional antedating response is conceived of as operating according to conditioning principles to *whatever* degree desirable. We assign any individual or combination of properties from the model to the theoretical construct guided by pragmatic considerations of predictive fertility and consistency of usage required for the integration of diverse areas. To reiterate this important point, a model may be applied to directly accessible (empirical) objects and events or to inaccessible and imaginary concepts of a theory. Though the levels of modular application considered are not discrete but represent extremes of a continuum, an important distinction should not be overlooked:

[2] Hereinafter the word "modular" is intended to pertain to a "model," not a mode.

while theoretical entities can be said to be anything we want them to be, this is not so for categories close to observation. The latter are spoken of only in an *as if* fashion. By invoking the conditioning model, perception, meaning, and verbal behavior are not said to be conditioned responses; it is only claimed that if represented and spoken of in such a fashion, important empirical consequences can be obtained. This point is well illustrated by Toulmin's analysis of the rectilinear propagation model of geometrical optics, "We do not *find* light atomized into individual rays: we *represent* it as consisting of such rays" (Toulmin, 1953, p. 29).

II. Models Functioning as Rules of Inference

Given the assumptions of some theory along with the experimental arrangements, a train of reasoning leads to the prediction sentences. From what source do the rules for such inference arise?

In the language used to talk about a theory, the term model may refer directly to a mathematical calculus or to a system of relationships from some other source such as electronic computers, the classical laws of motion, the laws of conditioning, etc. Any one of these separate systems in conjunction with the initial conditions of a given experiment may permit the prediction of what is to be observed. Here, model signifies *the rules* by which the theoretical symbols (some, at least, having been empirically coordinated) are manipulated to arrive at new relations; the rules by which one sentence is inferred from another or the theorems are derived. The probability calculus utilized in statistical learning theory (Estes, 1959) exemplifies such a mathematical model, while some of the relations holding among electronic communication systems play a role in providing the inference rules or calculus for information theory (Grant, 1954). Another example is the laws of classical conditioning which, alone or supplemented, are the means by which inferences are drawn in application of r_g theory to a given experiment (Kendler & Levine, 1951; Moltz & Maddi, 1956).

Calculational rules of mathematical systems and the semantic principles of natural language are themselves rules of inference for the symbolism involved. In contrast to this mode of derivation, Munitz (1957a, p. 42) recognizes the necessity for distinguishing a more specific set of inference rules provided by certain equations and supplementary textual commentary which prescribe the precise manner in which the theoretical terms and symbols are to be connected; these occasionally are termed "implicit definitions." Although some models may imply how assumptions and implicit definitions are to be formulated, the terms "mathematical model" and "conditioning model" apparently refer to the general inference principles employed in the first sense rather than to the implicit definitions. This is illustrated in r_g theory by the relation or implicit definition $r_g \rightarrow s_g$, for there is nothing in the laws of classical conditioning that requires the hypothetical response to have a hypothetical response-produced cue. But it is precisely the laws of classical conditioning that function as the basis for the rules by which we arrive at the consequences of the several implicit definitions. An additional illustration is provided by statistical learning theory's operator or difference equations, the specific choice of which is in no way dictated by the rules of mathematics, although the operators may be suggested by some second model. While the operator

equations determine the form of the learning function to be derived, it is only by the mathematical rules that the derivation itself is executed. It immediately follows that in the expressions mathematical model and conditioning model, the adjectives preceding the term model describe the *source* of the general inference principles. In both cases, this is a separate system external to the structure of the theory. The major source of statistical learning theory's inference rules are to be found in the texts on probability theory and the types of mathematics involved. The rules of inference for r_g can be found in the experimental literature on classical conditioning. For precision in derivation, it is obvious that the rules of mathematics are to be preferred. Furthermore, if it is not yet apparent, later analysis of specific theories will show that these modes of inference drawing do not follow the logic-book deduction of which some scientists and philosophers are so fond.

III. Interpretational Function of Models

The inference rules or calculus of r_g theory is formulated by amending and adapting the rules contained in the conditioning model; the model serves the additional function of interpreting the calculus. This is not the case for theories with inference rules primarily adopted from a mathematical calculus; the mathematical model may be supplemented with one or more additional models which serve to interpret and make intelligible the inference rules employed. Estes' statistical learning theory (1959), for example, makes use of a stimulus-sampling model; this second model provides a mode of representation functioning as a coherent way of speaking about the theory. Moreover, it functions as one possible interpretation of the theoretical terms. Formulae and symbols are rendered intelligible by the modular interpretation which also shows how to apply the theory and suggests procedures for extending the use of individual parameters and the theory as a whole. Thus, the stimulus-sampling model would tend to suggest that in extending the scope of statistical learning theory to include motivational phenomena, depreviational states would be conceptualized as producing differential configurations of the stimulus set available for sampling; this is precisely what Estes (1958) has done.

Some applications of the conditioning model suggest, in addition to inference principles, the rules for their application to the phenomena involved, the interpretation of the inference principles. Here, the modular interpretation produces propositions such as: the strength of r_g increases to some asymptote as a function of the quantity, time, and magnitude of consummatory experience in the goal box. In psychology such symptom relations are generally termed "coordinating definitions" which designate the class of propositions tying together theoretical terms with their associated empirical sentences. The model as an interpretation of a theory guides the formulating of coordinating definitions. Hutten (1956, p. 87) adds saliently, "The model so becomes a *link* between theory and experiment. We explain and test the theory in terms of the model."

IV. Models Providing Pictorial Visualization

Probably the most common meaning employed and service rendered by a model consists of the reproduction of the theoretical prototype in terms of mental pictures or images. Agents mediating this function range from a rigorously integrated separate system to a loose analogy with familiar sensory

experience. The popularity of this modular activity follows from the ubiquitous desire for an intuitively satisfying account of any theory. Preoccupation of classical physicists with model building of this limited pictorial type initiated the counter-view that model construction was a disreputable enterprise. Duhem (1954), for one, considered model construction to be both superfluous and the refuge of weak minds. Residual forms of this position are in evidence today; Carnap (1955, p. 209), while recognizing esthetic, didactic, and heuristic value, finds models nonessential for successful application of theory. Although this may be true of some theoretical activity, as a generalization it is deficient on several grounds and it neglects certain essential aspects of the behavior of a good number of scientists. In modern physics, although visual representation is no longer a prerequisite for the acceptance of a theory, the pictorial model may serve decisively in the initial phase of theory construction. While contemporary quantum theory cannot provide coherent visualization, it did develop from "Bohr's atom" which was associated with a pictorial model. Moreover, some current theoretical efforts concerning the atomic nucleus utilize the shell and water drop models. Axiomatization of a theory, or the attempts to do so, does not compromise this argument. Construction of an axiomatic system, apparently, is not attempted until theory construction is well under way, usually with the aid of some model. It is necessary, therefore, to carefully distinguish simple pictorial functions from the less trivial enterprises described in the previous sections. A model providing satisfying intuitive pictures may also serve one or more of the functions enumerated above, with influence upon theory construction and application that cannot easily be overrated. Conversely, a model providing *only* visual representation serves, at best, didactically; even then, it probably does more to mislead the student than to teach him. Consider Lewin's (1951) topological and field-theoretical models. Following Braithwaite (1953, p. 366n) we must agree that the essence of a calculus is not its symbolism but its inference rules, whereas Lewin's model functions as "a calculus that doesn't calculate." In contrast, the conditioning model, while possibly providing some S-R theorists with all the beautiful imagery associated with salivating dogs, also contributes the essential inference rules. The work of Staats and Staats (1957, 1958) provides an admirable illustration by their demonstrations that verbal meaning and attitudes may be treated as analogous to a conventional conditioned response whose laws furnish the calculus employed.

ILLUSTRATIONS OF MODELS

Although the functions enumerated here have been illustrated by examples from contemporary psychological research and theory, for some readers the distinctions made may still be rather vague. The situation may be remedied by analyzing different models and noting their functions in specific theories within cultivated areas of science. Certain theories of classical physics provide an excellent opportunity for comparative analysis with current theoretical efforts in psychology. Additional functions will be served by such an analysis of at once demonstrating the initial contention that models are utilized in an essentially similar fashion in both classical physics and psychology. At the same time, some light may be cast upon a question that has elicited a good deal of polemic: the problem of the emulation of physics by psychologists. The r_g theory, statistical learning theory,

and the classical kinetic theory of gases have been selected to illustrate the role of the model in a theory. The rigorous methodological analysis to which the latter theory has previously been subjected is the basis for its selection. The language to be employed in this illustration will be accessible to almost every student of psychology; we turn, now, to that task.

The Kinetic Theory of Gases

Let us first observe the pictorial model of the kinetic theory in its most limited form. A gas is represented by this initial model as consisting of minute invisible particles (molecules or atoms) in incessant motion, colliding with one another and with the walls of any restricting container; at a given instant, most of the particles are separated by vacant space. Consider, now, the interpretation by means of the pictorial model of the known properties of a gas residing in a container composed of rigid walls, one of which is movable in the manner of a piston. The adjustable wall may be moved inward; this is interpreted as a reduction in the available space between the particles and accounts for the property of compressibility of a gas. While pushing in the wall we experience resistance against our efforts. As we continue to reduce the space, the resistance increases ever more. The model attributes this to an increase in the number of collisions following from a reduction in volume and resulting in an increase in the velocity of the gas particles. Boyle's Law, which states the relationship between volume and pressure, thus is attributed to an increase in the rate of impact between the particles and the wall of the container, which is part of the general picture of increment in the number of collisions among the particles produced by the decrement in the space between them. But the diminution in volume has increased not only the pressure but also the temperature. This is accounted for by the increased velocity of the particles adding to their kinetic energy. Thus, the law relating temperature to pressure is acknowledged. While the presentation, thus far, is not dissimilar to D. Bernoulli's original hypothesis (D'Abro, 1951, p. 381) we have proceeded somewhat beyond the initial model which essentially involves a picture of mass-points in motion functioning as a representation for and way of talking about the hypothetical ideas and postulates of the initial theory.

Introducing additional models or the amendment of the original provides the inference rules. The first addition involves the well developed laws governing a separate phenomenon which are applied to the ideas of the pictorial model. This may be termed the dynamical Model II [2] for the theory under consideration. Here, the gas particles are conceived as behaving analogously to medium sized bodies such as billiard balls, rocks, or planets: the laws of classical mechanics governing the motions of the latter and the principles of dynamics describing their energy states are ascribed, approximately, to the motions and energy states of the imaginary gas particles pictured by the Model IV. The laws provided by the dynamical model are in mathematical form and are themselves supplemented by an additional Model II, the calculus of probabilities. Thereby, the rules of reasoning or calculus of the theory are formulated, by means of which consequences are derived from the initial theoretical terms. But the combining of Models II cannot, itself, be given any rules, for the essential ingredient is the creative imagination of the scientist.

Following Campbell's (1920) de-

[2] A Roman numeral designating the specific type of model will be affixed where this may be in doubt.

tailed analysis, let us schematically describe one of the more elementary derivations in a suitably idealized and simplified fashion. The postulates of the theory may be represented by terms which include the symbols: t, m, v, l, n, and (x, y, z). The postulates, which we need not reproduce, consist of several implicit definitions in the form of equations relating these theoretical variables and associated textual commentary. Now, (x, y, z) may be pictured by the Model IV as rectangular coordinates for the position of each of the imaginary particles: m their mass, v their mean velocity, n their number, t as time, and l as the length of an edge of the hypothetical container. The implicit definitions relating the postulated variables *are approximate in form to the laws which would govern the motions of such an isolated system of entities pictured by the model.* From the initial terms and their postulated interrelationships, the expression

$$p = \frac{n\, m\, v^2}{3l^3} \qquad [1]$$

is derived in accordance with the mathematical rules involved.[4] For *some* of the individual theoretical terms and several combinations of them, coordinating definitions are stated relating them to the appropriate empirical terms. The coordinating propositions are suggested by the pictorial model in its interpretative function. Thus, coordinating l with the length of a cubical container holding a real gas, it follows that l^3 is the volume V of the gas. Likewise, p is coordinated with the pressure P on a wall of the vessel, and $m\, v^2/a$ with the absolute temperature T of the gas.[5] Substituting the empirical terms P, V, T in the theoretically dederived Expression 1, the term $a\ n/3$ remains, which is a constant k, and we have,

$$P\, V = k\, T, \qquad [2]$$

the familiar gas law relating temperature, pressure, and volume, which is applicable over an empirically determined range for a given type of gas.

Returning to the derivation of Expression 1, application of the inference rules provided by the laws of dynamics requires certain assumptions concerning properties of the modular particles; namely, they are infinitesimal, so that their diameters and orientation in space may be ignored. In addition, they are assumed to be perfectly elastic. Nonelastic particles would suffer a reduction in velocity with each impact upon the container wall and eventually their motion would cease entirely, precluding the derivation of consequences in agreement with observation. The critics of certain theoretical assumptions in psychology would do well to ponder the

[4] The term "p" is a compact way of writing a more complex arrangement of the above symbols involved in the postulates. The actual derivation is frequently performed in the Gibbsian manner of treating a gas particle's three components of position and three of momentum as the coordinates of a single "phase point" located in a "phase space" of six dimensions or $6N$ dimensions for N particles (Jeans, 1940, p. 17 ff). For the present considerations, this illustrates the not infrequent situation of identical consequences being derived from somewhat different assumptions.

The distinction usually made between an ideal gas and a real gas will be avoided. Instead, the propositions concerning a real gas will be amended with a statement concerning their range of validity. This alternative method will be employed in accordance with the view that a scientific law cannot be regarded as a universal proposition both on empirical and logical grounds. With respect to the hypothetical ideas of a theory, as here viewed, these are always ideal situations, since they are creations of the imagination directed toward executing derivations in agreement with experiment and the achievment of mathematical simplicity.

[5] For a definition and analysis of the term "a," consult the work of Campbell (1920, p. 127).

implications of the assumptions of an *infinitesimal* and *perfectly elastic* particle, properties that it is impossible to assign to observable objects.

Campbell (1920) discriminates two processes for extending a theory. It will be recalled that only some of the postulated variables were coordinated with empirical terms. The formulation of additional coordinating definitions for the uncoordinated terms illustrates the first method of theoretical extension. A second method of theoretical development involves making amendments to the postulated terms and the equations expressing their interrelationships. This second method proceeds as follows: the previous assumptions are modified or amended and new theoretical terms are introduced into the postulates corresponding to the additional assumptions. The pictorial model may prescribe this extension. Thus, viscosity relations of a gas may be derived by altering the previous postulates with a term suggested by the pictorial-dynamical model corresponding to a diameter for the hypothetical particles. Consideration of the space occupied by the modular particles and their mutual attractions leads to other derivations. This accumulation of assumptions following from the extension of ideas contained in the model has been termed "modular deployment" by Toulmin (1953). In the present theory, experimental agreement breaks down when the model is deployed to include internal rotations of the imaginary particles. General failure of observational agreement also occurs with the attempted extension of the theoretical *scope* to extreme ranges of temperature and pressure. In both instances, quantum mechanics supersedes the classical kinetic theory.

r_g Theory

Turning to r_g theory, let us first examine the pictorial model involved. A rat is placed in a T maze, one arm of which is baited with food; the second is empty. A noncorrection procedure of training is employed. On the trials during which the correct goal box is entered, the animal executes unconditioned responses (UR) of approach movements, chewing, salivating, etc., to the unconditioned stimulus (US), food. On subsequent trials, stimulus objects and patterns of the choice-point and starting arm are encountered at a point in space prior to the food, or US. Since these choice-point stimuli are located spatially antecedent to the US, they are, therefore, encountered at some temporal interval prior to the food or US, depending on the animal's rate of locomotion. The antecedent stimulus patterns come to elicit imaginary or invisible conditioned responses (CR), such as chewing and salivating, which logically consist of components of the empirical UR to food. These invisible antedating conditioned responses (r_g) are acquired in a fashion exactly analogous to Pavlovian conditioning of observable responses. The unobservable r_g, in turn, produces a hypothetical proprioceptive response-produced stimulus (s_g), which likewise functions in the fashion of an overt and observable stimulus.

Cues at the choice-point may consist of different visual texture or brightness patterns for each of the maze arms, as well as proprioceptive consequences of locomotion and receptor orientation toward the left or right end box. One and only one of these choice-point stimulus patterns is consistently followed by the US, food. Thus, only this specific set of stimuli will selectively begin to act as a CS and elicit the hypothetical conditioned response, r_g. Evocation of r_g will occur with increased frequency and amplitude, the greater the spatial proximity between the set of cues and the goal object, or the greater the sim-

ilarity between the choice-point cues and the goal box stimuli. This, of course, follows from classical conditioning laws dealing with *CS-US* interval and generalization. It is possible to imagine a sequence of events occurring during a trial early in training which is terminated by the rewarded or correct response: *S* locomotes to the choice-point where *VTE* behavior occurs, after which *S* orients its musculature and receptors toward the cues of the rewarded end box. Since only a moderate amount of training has preceded, the correct cues elicit r_g with low frequency and minimum amplitude. Orienting responses are followed by penetration into the correct end box which terminates with the consummatory or goal response. Notice what is imagined to occur: since the correct choice-point stimuli have been followed by the *US* of food, these choice-point cues have increased their strength of evocation of the conditioned response, (r_g). At the same time s_g, which is available only when r_g occurs, would be selectively present prior to the performance of the correct instrumental response. With prolonged training, the strength and probability of r_g elicitation by the correct cues are continuously enhanced via classical conditioning. A concomitant increment in frequency of occurrence of s_g takes place. Likewise, by means of S-R contiguity, s_g elicits the appropriate selective-learning response with greater frequency. In this fashion, the frequency of the correct response approaches some asymptote, which for the present experimental conditions is unity.

A basic form of selective-learning has been accounted for by the model without appealing to some special mechanism of reinforcement; the changes in behavior are mediated solely by classical conditioning and S-R contiguity. It might be questioned: why not explain the behavior by molar S-R contiguity alone and not introduce invisible events? As we shall see, this nonobservable system of events mediates other predictions for several different initial conditions, most of which cannot be derived and integrated by molar principles alone. An exactly analogous situation exists between thermodynamics and the kinetic gas theory.

Deployment of the model has made the picture more complex: a class of events has been introduced into the negative end box. Frustration and avoidance responses are assumed also to "move forward" by means of classical conditioning to the incorrect cues at the choice-point. To pursue this phase of modular deployment is not necessary for our purposes. Let us instead examine that which has already been presented. We have proceeded beyond the pictorial model and described the inference techniques of the theory. The pictorial model itself essentially involves the idea or picture of objects and events occurring at the terminal portion of a behavioral chain influencing prior events. Terminal goal box events function as *US*'s whose appropriate *CR*'s "move forward" to determine and mediate events occurring earlier in the behavioral sequence. Serving as a representation for and manner of talking about the ideas of r_g theory, the pictorial model provides a seemingly necessary service.

The model of classical conditioning also provides the inference rules or calculus of r_g theory, which for the most part is the product of Spence's (1951a, 1951b) creative theorizing. Nonobservable r_g is conceived as behaving analogously to observable conditioning: the acquisition and extinction laws of the latter are ascribed, approximately, to the former. In conjunction with the initial conditions of a given experiment, the conditioning laws mediate the der-

ivation of specific predictions, as has been demonstrated. Utilizing one of the many examples available (Amsel, 1958; Kendler & Levine, 1951; Moltz, 1957; Spence, 1956), let us again examine the manner in which the laws of conditioning serve as the model and provide the inference rules. Moltz (1957) has demonstrated that the observations concerning latent or nonresponse extinction may be derived by the calculus of r_g. Modified only slightly, Moltz's derivation proceeds as follows. Placing an animal in a previously rewarded but now empty goal box results in the repeated evocation of r_g by the cues that were in close proximity to the now absent goal object. Since the *CS* (goal box cues) eliciting r_g is no longer followed by the *US* (food), the extinction laws of classical conditioning would require that the hypothetical *CR* (r_g) should suffer a reduction in strength. Invoking the generalization of extinction laws, it can be reasoned that the frequency of r_g evocation at the choice-point is reduced and that the reduction is a function of the degree of similarity between choice-point and goal box cues. Since a concomitant reduction in s_g occurs, it follows that a decrement in the probability of the observable choice behavior must occur. Such a reduction in choice behavior as a consequence of latent extinction had been previously observed. But once again utilizing the inference rules provided by the model, consequences not yet observed were derived. Moltz selected two conditioning laws as inference rules: (*a*) the rate of evocation of an observable conditioned response covaries with relevant drive during extinction, and (*b*) the reduction in response strength during extinction is a monotonic increasing function of the number of response evocations in the absence of the *US*. Notice that the logical status of the two conditioning laws has now changed from empirical propositions to inference rules. The initial conditions of an experiment must now be stated in order to derive the prediction sentences. Training may first be administered in a T maze. The animals must then be divided into a number of groups with different drive schedules and placed in the empty goal box. In accordance with the drive law (*a*), the animals with the highest motivation should produce the greatest emission rate of the imaginary response, r_g. These subjects, according to the extinction law (*b*), should show the greatest reduction in the strength of r_g. Thus, the decrement in choice behavior on subsequent test trials should covary with the drive level present during placement in the empty goal box. Experimental verification for this prediction was obtained (Moltz & Maddi, 1956).

Having demonstrated that the conditioning model of r_g theory provides in addition to pictorial and representational function the rules of reasoning, we need only consider the model's interpretative function. Although coordinating definitions were systematically formulated during the derivation of observable consequences, they were not explicitly denoted. Examining first the empirical antecedent variables, coordinating definitions may be formulated by imagining that r_g is an ordinary conditioned response. This is an alternate way of stating that the conditioning model is being utilized. Thus, the strength of r_g is a negatively accelerated increasing function of the number of trials that the eliciting stimulus of r_g is followed by the reward or *US*. The strength of r_g is a decreasing function of the temporal interval between its eliciting stimulus and the *US*. In this fashion, the various relationships between an observable *CR* and the variables of which the *CR* is a function

define the empirical coordinates of r_g. The term define in this last statement must be qualified. It will be recalled that in the analysis of the kinetic theory of gases, one method of developing the theory involved the formulation and revision of coordinating definitions. Thus, coordinating propositions are to be understood as hypotheses rather than conventions: those that prove fruitful are retained, the useless coordinates are discarded. Finally, considering the consequent empirical variables, the probability of the correct response in selective learning is coordinated with the availability of s_g at the choice-point.

Having demonstrated the role of the model in r_g theory, an evaluation of the system might be in order. Aside from its apparent promising potential, the primitive state of the theory precludes any definitive judgment. However, the conditioning model of r_g theory does appear to function in a fashion quite similar to the mechanical model of the prequantitative (Bernoulli's) kinetic theory. Accordingly, one wonders if the conditioning model is destined to play the same role in psychology that the mechanical model served in physics.

Statistical Learning Theory

We shift now to an examination of a multiple model system. Estes' probability learning theory (1959) offers some interesting contrasts to r_g theory. As we shall see, the pictorial model of Estes' theory invokes nonobservable stimulus occurrences while r_g theory appealed essentially to nonobservable response events.

If a T-maze experiment with a correction procedure is employed for the purpose of illustration, then an analysis may be rendered that is suitably simplified for the present purpose of studying the functions of the several types of scientific models. Let us, therefore, consider such an experiment. Over a large number of trials the reward is randomly placed in the left arm 70% of the time; on the remaining 30% of the trials, the reward is in the right arm. When an animal selects a nonrewarded arm, it is permitted to retrace. In this fashion, each trial terminates with reinforcement. The initial right or left turn is defined as the response for that trial. These two response classes are mutually exclusive and exhaustive.

The pictorial model associated with Estes' theory permits us to imagine the external environment of the maze and the internal environment of the animal as consisting of a very large but finite number of invisible stimulus elements. On any given trial, a sample of these stimulus elements is available. Each element has an equal probability of being included in the sample (this is assumed for the present type of experimental situation). At any specific moment, a given stimulus element is in an associative state with (conditioned to) one and only one response. In addition, the probability of a given response is dependent upon the number of stimulus elements conditioned to it. The sum of the probabilities of the available, mutually exclusive, and exhaustive response classes equals unity: one of them must occur.

During the initial trials in the T maze, the two alternative responses may sometimes occur with equal frequency and it is possible to imagine that an equivalent number of elements of the stimulus set are conditioned to the two response classes at the start of training. With continued training, the ratio of stimulus elements conditioned to each of the response classes undergoes a change. When the rewarded arm is ultimately selected on each trial, all the stimulus elements in the sample available during that trial are conditioned to the reinforced alter-

native. It will be recalled that a response to the left arm was assigned a reinforcement schedule of 70%. Regardless of the initial response executed, and as a result of retracing, 70% of a large series of training trials will terminate with a response to the left arm. Likewise, 30% of the trials terminate in the right end box. Thus, as training progresses, the stimulus set tends to approach a composition of 70% of the elements conditioned to the left response and 30% associated with the alternative response. Since the content of the subset of stimulus elements sampled on any trial approximates the composition of the total set, an initial response to the left arm will approach a probability of .7 with continued training. Thus, 70% of the initial responses to the left end box will be observed over a long series of trials.

So much for the pictorial model which represents the experimental situation as a series of imaginary stimulus events, the composite set of which undergoes a cumulative change in associative connection. Unavoidably, other matters such as the assumptions or postulates of the theory were included. To these and to the rules of inference or mathematical model we now direct our attention.

Following the thorough presentation of Estes (1959), and Estes and Straughn (1954) and introducing some modifications for expository purposes, let us partially describe the derivations for the previously portrayed T-maze conditions. The theoretical postulates involve combinations of such symbols as, $F_{(n)}$, θ', π', A_1, A_2, n, etc., and the related textual commentary. Interpreting these symbols in a strict theoretical language by means of the pictorial model, A_1 and A_2 may be imagined as the two theoretical response classes available, n as the number of theoretical trials, π' as the probability of the hypothetical reinforcing event following the occurrence of A_1. In addition, θ' may be conceived of as the probability of any single stimulus element being included in the sample available on a given theoretical trial, and $F_{(n)}$ as the probability that a given stimulus element is connected to imaginary response A_1 after trial n.

A few examples from Estes' postulate set will be helpful. One axiom previously indicated in the discussion of the pictorial model is expressed by the following proposition:

$$\text{“}F_{(n)} = (1 - \theta')\ F_{(n-1)} \qquad [3]$$

when response A_2 is reinforced on trial n.” Interpreted by the pictorial model the equation states: after a reinforcement of response A_2 on trial n, the probability or proportion $F_{(n)}$ of the elements conditioned to response A_1 equals the proportion of stimulus elements *not* sampled $(1 - \theta')$ on trial n that were already conditioned to the A_1 response $(F_{(n-1)})$ at the end of the previous trial. This is a consequence of the terminal response A_2 on trial n during which all the elements sampled were conditioned to A_2. The postulate for the consequences of reinforcement of response A_1 during these imaginary events is given by the equation,

$$F_{(n)} = (1 - \theta')\ F_{(n-1)} + \theta'. \qquad [4]$$

Expressing it in an algebraically equivalent form,

$$F_{(n)} = \theta'\ (1 - F_{(n-1)}) + F_{(n-1)}, \qquad [5]$$

may facilitate the interpretation of the postulate. Thus, the term '$(1 - F_{(n-1)})$' may be described as the probability that an element was *not* conditioned to response A_1 at the end of the previous trial $(n - 1)$, since the probabilities sum to unity. Thus, loosely inter-

preted by the pictorial model, the proposition reads: after a reinforcement on trial n, the probability or proportion of the elements $F_{(n)}$ conditioned to A_1 after trial n is equal to that proportion of the elements sampled (θ') which were not previously conditioned $(1 - F_{(n-1)})$, plus that proportion of stimulus elements $(F_{(n-1)})$ already conditioned to response A_1. In this fashion, the postulates and hypothetical ideas of the theory may be interpreted by means of the pictorial model.

Starting with the theory's set of postulates, parts of which are expressed in the difference equations 3 and 4, derivations are made by means of the inference rules or mathematical models which include the separate systems of the calculus of probabilities, the rules of algebra, and the methods of mathematical induction. Among the theorems derived (Estes, 1959; Estes & Straughn, 1954) is the function,

$$F_{(n)} = \pi' - (\pi' - F_{(1)})\ (1 - \theta')^{n-1} \quad [6]$$

which expresses the acquisition curve for the imaginary events.

Once again guided by the pictorial model, coordinating definitions are formulated. For the empirical counterpart of the T-maze situation previously described, $F_{(n)}$ is coordinated with $P_{(n)}$, the average probability of an A_1 response for a group of subjects. The A_1 response is coordinated with that class of empirical responses involving an initial selection of the left end box. Coordinating π' with π, the latter term is defined as the empirical ratio of reinforcement for the response coordinated with A_1. In the T-maze situation exemplified, the reinforcement schedule for the left response is 70% or .7; in this situation $\pi = .7$ by definition. Finally, n is coordinated with N, the number of empirical trials, one of which is defined as the sequence of events initiating in the start box and terminating in the rewarded end box. The concept 'θ',' let us simply say, is coordinated with the empirical acquisition rate θ. Substitituting these terms in equation (6), we have the empirical learning function for the T-maze situation previously portrayed,

$$P_{(N)} = \pi - (\pi - P_{(1)})\ (1 - \theta)^{N-1} \quad [7]$$

which is stated in terms of the data language. When N is large, the extreme right hand term approaches zero, since $(1 - \theta)$ is less than unity. The function, therefore, reduces to $P_{(N)} = \pi$. This agrees with the observation that asymptotic response frequency for a correction procedure T-maze habit approaches the reinforcement ratio when frequency of reinforcement is set at π and $(1 - \pi)$ for the two alternative responses. The empirical scope of this law has not been determined. That is, the sets of initial conditions (experimental arrangements) within which the law is correct await empirical demonstration.

The several meanings and functions of scientific models have been demonstrated in statistical learning theory. A characteristic feature of Estes' theory obviously is that the rules of inference employed are entirely mathematical in form. As recently as the late 19th century, a good number of experimental physicists were openly expressing their distaste for mathematics in their science. Consequently, it would be surprising not to hear the same sort of thing from some contemporary psychologists. Perspective gained with passage of time as well as the fantastic success of mathematical physics silenced the critics. A good case is yet to be made against the expectation that the same might occur in psychology. Be that as it may, a cogent point is often made: fancy mathematics is no substitute for creative imagination. It

would appear, however, that Estes' theory contains a good deal of both.

CRITERIA FOR EVALUATING A MODEL

The modes of operation of several models within their respective theories have been demonstrated. It becomes necessary now to formulate criteria for evaluating a given model. Following Toulmin's (1953) analysis of science, which was influenced by Wittgenstein's (1922) views, several grounds for judging a model may be stated.

Deployability

The degree to which the terms in the model in their primary context of usage can successfully be brought to the new setting. In r_g theory, deployability means the extent to which the nonobservable r_g can be assigned the properties of its observable counterpart, the conditioned response. As additional properties and laws of the separate system are assigned to r_g, the conditioning model is being deployed.

Scope

The range of phenomena to which the model is applicable. This means the number or extent of facts and data that may be derived by use of the model. According to this view, a theory does *not* contain formal limits; instead, the scope of applicability is empirically determined.

Delineation of the scope of a theory provides the guides and incentives for subsequent theorizing. This may take the form of changes in the initial theory or the construction of a more comprehensive system. In the latter case, the original theory frequently becomes a first approximation or a special instance of the general theory: the equations of the comprehensive theory reduce to the equations of the limited system for the special cases involved. The efforts of Estes and other mathematical model builders make it possible to envisage this future state of affairs in psychology.

While "scope" refers to the *empirical* derivatives of a theory which are generated with the aid of a model, "deployability" is an attribute of the set of relationships or meanings contained in the model that are employed in formulating the *logical* propositions of the theory. Generally, the more a model is deployed the greater will be the scope of the theory; the reverse, however, is not true.

Precision

For psychology, this in the present paper refers to the degree to which the consequences of a theory are unequivocally derived through application of the inference rules provided by the model. This feature is of special importance since the prequantitative character of most models in psychology often permits contradictory derivations.

Several implications of the viewpoint that generated these criteria merit specific consideration. A fundamental point concerns the criterion of truth. Although the terms true and false are applicable to empirical sentences, these adjectives are devoid of meaning when applied to a model or the theory the model serves. A model has lesser or greater deployability and scope and a certain degree of precision, but not truth or falsity.

An adjunct to the three judgmental criteria is the dichotomy between models providing calculi, coordinating definitions, and related functions and those yielding *only* pictorial imagery. The latter, in psychology, have taken the form of cognitive maps, S–R switchboards, behavioral fields, and a variety of peculiar things in the nervous system. When mistaken for more serious instruments, the *exclusively* pictorial model can generate a good

deal of useless experimental labor, a point eloquently presented by Kendler (1952). Where the inferential or interpretative function is sacrificed for the best intuitive picture such as in a model reflecting, "the existential richness of human life . . ." (Allport, 1955, p. 11), the scientist usurps the poet's function.

One consequence of confusing modular terms with empirical sentences is the variety of cases continuously made against one or another model. For example, Harlow (1953) contends that simple behavior has explanatory value only for simpler phenomena and provides no information concerning complex behavior. This view loses all urgency when one seeks the basis for the distinction between simple and complex. Occasionally, the distinction is held to be self-evident. However, this cannot be seriously regarded, as that which is considered self-evident for one generation of science is frequently believed to be absurd by some other generation. More often, the distinction between simple and complex phenomena is predicated upon the more extensive knowledge accumulated concerning the former: what is relatively well understood is simple; that which is less well known is complex. Harlow (1953) and Asch (1952) have been most critical of the "simplicity" involved in the conditioning model. We may look forward to the day when the research being done by these scientists transforms "complex" incentive-motivational, exploratory and social behaviors into "simple" phenomena.

THE ROLE OF ANALOGY

There are no sufficient a priori grounds for determining how well some separate system will function as a theoretical model for another realm of phenomena. The successful theorist's imagination does, initially, grasp an analogy between the data of interest and the separate system. As the basis for selecting some model, recognition of a critical analogy has sometimes produced the most incredible accomplishments: de Broglie's wave mechanics and Einstein's relativity are two instances. Successful apprehension of analogy is not limited to the most illustrious examples, for as Munitz (1957b) has demonstrated, analogy has served a core function in man's interpretation of his environment from Babylonian mythology to modern science. Consequently, the logician has exerted some effort in the attempt to torture the notion of analogy into a neat classificatory scheme. With the exception of the recent heroic efforts of Braithwaite (1953), the basis for the analogical relationship between a model's separate system and the ideas of the theory it serves has not been explicated.

MODULAR THEORIES AND MODULAR CONSTRUCTS

One corollary of the methodological position outlined is the required distinction between constructs introduced by a model and those defined immediately in terms of observables. Stimulus elements and r_g are *theoretical or modular constructs*, whereas drive, defined in terms of the known laws concerning the energizing and facilitative effects of deprivation, might be termed an *empirical construct*. An essentially similar distinction has recently been made by Ginsberg (1954), so we need not pursue it further except for one additional consideration. Dichotomizing constructs along the lines suggested might provide one basis for categorizing scientific theories. Borrowing the classification of *empirical construct theory* and *axiomatic-model theory* from Spence (1957), we would

suggest that whereas the former class of theory employs empirical constructs, the latter utilizes modular or theoretical constructs. Examples of axiomatic-model theories have been analyzed here; there are no examples of relatively pure empirical construct theory in psychology. Interestingly enough, Spence's (1956) theory might be considered a mixed type, as he employs empirical constructs such as drive and habit and theoretical constructs such as r_g and s_g.

In the course of the last century, theories of the axiomatic-model type were considered extremely objectionable to a number of scientists and philosophers such as Mach, Duhem, and Ostwald. Characteristic objections concerned the employment of concepts at another level of discourse, that is, the appeal to suprasensible occurrences. The great success of the axiomatic-model type of theory in classical physics eventually silenced the positivistic critics. In contemporary psychology, however, this viewpoint has sired the school of radical empiricism. Although the ingenuity and imagination of Skinner's experimentation are probably unequaled, his views on theory (Skinner, 1950) should be severely questioned.

THE MODEL AND REALITY

On pragmatic grounds, most scientists find it necessary to acknowledge an external world independent of the observer. As a consequence, discourse is generated concerning the relationship between the models and constructs of science and the phenomena these represent. Since a successful model enables us to predict the future outcome of sets of events, the model is sometimes assumed to be a literal description of reality. For example, it might be argued that the kinetic theory predicts the behavior of gases and since a gas must be composed of something, why not the molecules pictured by the model? Such an assumption in no way interferes with the scientists' activity and may be disregarded. However, one consequence of that view is not so harmless. Occasionally it is argued that if there is a reality, then one and only one model can provide the best description of it. This last proposition and the assumption of reality correspondence upon which it is based are seriously discredited by the very content of physics and psychology. Numerous examples are available of several models serving the same class of events. Conversely, a single model can function in behalf of independent classes of phenomena. Whittaker provides an admirable illustration of the latter state of affairs:

> . . . it happens very often that different physical systems are represented by identical mathematical description. For example, the vibrations of a membrane which has the shape of an ellipse can be calculated by means of a differential equation known as Mathieu's equation: but this same equation is also arrived at when we study the dynamics of a circus performer, who holds an assistant balanced on a pole while he himself stands on a spherical ball rolling on the ground. If we now imagine an observer who discovers that the future course of a certain phenomenon can be predicted by Mathieu's equation, but who is unable for some reason to perceive the system which generates the phenomenon, then evidently he would be unable to tell whether the system in question is an elliptic membrane or a variety artiste (Whittaker, 1942, p. 17).

SUMMARY

The functions of models in theory construction were analytically categorized as (*a*) representational, (*b*) inferential, (*c*) interpretational, and (*d*) pictorial. Distinctions introduced were exemplified in the kinetic theory of gases, r_g theory, and statistical learning theory. Implications of the anal-

ysis for current methodological problems in psychology were examined.

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THE JUDGMENTAL PROCESS IN PERSONALITY FUNCTIONING

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Consistent with their general cognitive bias, many psychologists have actively been engaged in extending judgmental principles from the psychophysics laboratory to the social world. Sherif, for example, who has devoted much of his professional life to this endeavor (1935, 1936, 1945–1946, 1956), continually has emphasized the importance of judgmental processes in social phenomena. Thus, writing some fourteen years ago in this journal, he and Cantril attempted to apply the psychology of perception and judgment to the concept of "attitude" (1945, 1946). From their point of view, these areas were intimately bound together. When an individual forms an attitude, they maintained, he learns to make a class of judgments in the course of which an issue or object is related to an appropriate frame of reference. More recently, Helson (1948) has suggested the relevance of his adaptation-level theory for a wide range of behavioral data. The present paper, in a sense, follows the same tradition. Here, as in the earlier works, the focus is upon cognitive processes. But more than this, together with these writers, we assume the underlying unity of psychological principles. To paraphrase Sherif and Cantril (1945, pp. 299–300), judgments made in the experimental laboratory and judgments in the most complicated social situation follow the same laws, ". . . the basic psychological substrata functioning in both instances are the same in nature." [1]

[1] This thesis, obvious though it may seem to many readers, is not universally shared in social psychology. Tagiuri and Petrullo (1958) prefer to emphasize the differences rather than the similarities between the "person perception" and "thing perception." They point out that in responding to people we frequently assume that they are "capable of watching, perceiving, remembering, and waiting for opportune circumstances." We experience them as directing themselves to us, "with intentions, attitudes and feelings," and these experiences affect the interaction between them and ourselves (p. xi).

However, these experiences and assumptions concerning the cognitions and motivations of other stimulus objects serve only to complicate rather than to transform the picture. By and large, the assumptions are our "laws of nature" by means of which we make inferences as to the future behavior of the people concerned, but similarly we utilize other "laws" (more or less naive depending upon our sophistication) to predict the behavior of inanimate objects. Furthermore, these assumptions at times become relatively unimportant in affecting reactions to others. Just as money may become valued because it is instrumental to need satisfaction, so do we often learn to value other people for their instrumental significance.

Categorization and Judgment

In each case, regardless of the situation in which the judgment is made, the "psychological substratum" involves the act of categorization. As Bruner has put it, when "we stimulate an organism with some appropriate input . . . he responds by referring the input to some class of things or events" (1957, p. 123); ". . . whatever is perceived is placed in and achieves its 'meaning' from a class of percepts with which it is grouped" (p. 124). For our present purposes it is worth considering these groupings as categories and supracategories within which the smaller sets can be ordered.

Confront the *S* with a number of small metallic objects and he may classify them as weights, with some being relatively light and others heavier. The supracategory defines the continuum, or continua, along which the smaller categories are placed. It establishes the relationships that may exist among the smaller sets (e.g., heavier or lighter). Judgment, then, is a function of these relationships.

Two familiar kinds of judgmental phenomena are of particular concern to us here: contrast and assimilation. Without attempting to account for these phenomena (explanatory hypotheses have been offered by Helson (1948) and Peak (1958), this paper will try to show that conditions analagous to those producing either contrast or assimilation in the psychophysics laboratory will yield essentially similar results with self- and other-evaluations. If the distinction can be made, our purpose is description rather than explanation. This being the case, a crude model of the judgmental process will suffice. Translating the fact that all judgments are made with respect to a frame of reference, we can say these evaluations are a function of the relationship between some standard or anchorage category[2] and the category in which the evaluated stimulus would be placed by an observer who had not experienced the standard. If the distance between these two categories is relatively small there is *assimilation*, i.e., the *S* locates the stimulus in some category *between* the standard and the observer's judgment, or even *in* the standard category. On the other hand, *contrast* takes place when this distance is relatively great. In this case, the *S* places the evaluated stimulus further away from the standard than does the observer not affected by the standard (Peak, 1958, pp. 335–336, cites the experimental evidence for these propositions).

Two experiments by Hovland and Sherif illustrate the relevance of contrast and assimilation for social psychology. In the first of these (Hovland & Sherif, 1952) groups of strongly involved judges, some pro-Negro, others anti-Negro in their attitudes, were asked to sort 114 opinion statements in terms of their favorableness toward Negroes. The rather indefinite statements in the middle of the scale were displaced away from the judges' own positions (i.e., there was contrast), contrary to Thurstone's assumption that the judges' attitudes would not effect their item sorting in his "equal-appearing intervals" scaling technique. It is likely, as I will attempt to show later, that the strongly involved *S* perceived a clear difference between his own position, the anchorage, and the beliefs reflected in the items. In other words, the distance between these categories was relatively great. Since the items' true position was indefinite, contrast could take place readily.

The second study (Hovland, Harvey, & Sherif, 1957) demonstrates both contrast and assimilation. Three communications dealing with the then locally important issue of prohibition were delivered to *S*s in Oklahoma and Texas, one communication advocating the strong "wet" position, another strongly "dry," and the third being moderately "wet." The investigators report that the *S*s' evaluations of the communicator's position was a function of the distance between their own attitude and the communicator's "true" position. The *S*s closest to the communicator reported his beliefs relatively accurately; those not too far from the communicator tended to

[2] Helson (1948) maintains that an "adaptation-level, defined operationally in terms of the stimulus evoking a neutral or indifferent response" (p. 298) serves as this frame of reference.

judge his opinion on being more like their own than it actually was (assimilation); while those furthest from the communicator saw him as advocating a view further away from themselves than it really was (contrast).

On the basis of these studies, then, there would seem to be little doubt that contrast and assimilation effects take place in social judgments. A more pressing problem is the necessity of showing the usefulness of the present categorization model for the understanding of these phenomena, and this can be done by citing two additional experiments. The first of these is mentioned by Bruner (1957):

> . . . Helson's law of adaptation level states that the subjective magnitude of a singly presented stimulus depends upon the weighted geometric mean of the series of stimuli that the subject has worked with, and the ingenious experiments of Donald Brown have indicated that this adaptation level is influenced only by those stimuli that the subject considers to be within the category of objects being considered. Ask the subject to move a weight from one side of the table to the other with the excuse that it is cluttering up the table, and the weight does not serve as an anchor to the series, although it will show a discernible effect if it is directly included in the series being judged (p. 128).

Apparently, for a stimulus to be included in and affect the nature of the standard category it has to be seen as appropriate to that category. It has to be grouped with the other anchorage stimuli. This grouping process obviously also can influence the perceived distance between the standard and the evaluated stimuli. Richard Schilling conducted an experiment under the writer's supervision in which the *S*s had to judge the over-all "goodness" of 11 personality traits by orally assigning ratings on a 13-point scale. The first seven traits (all "good" or all "bad" depending on the condition) served as the anchorage. After giving a judgment for each of these traits, all of the *S*s then evaluated four neutral traits one at a time. Half of the *S*s had been informed at the beginning of the study that the traits all referred to one person, while the remaining *S*s were told the traits did not describe any one individual. The results showed a significant contrast effect; the evaluation of the neutral traits was displaced away from the evaluations of the preceding seven stimuli. However, the interaction of "good-or-bad anchorage" with the "same person-different people" instruction also was significant; there was a smaller difference between the "good" and "bad" anchorage *S*s in the evaluations of the neutral traits under the "same person" instruction than under the "different people" condition. In the former treatment the *S*s presumably were more likely to group the neutral traits together with the preceding seven traits. This placing of the traits in one larger category ("all describe one person") apparently then served to lessen the psychological distance between the anchorage and neutral traits, thereby lessening the contrast effect.

If this interpretation is correct, the results of this experiment can clarify some of the findings obtained by the Yale Attitude Change Project. Working under the auspices of this project, Luchins replicated the essential features of Asch's study of the primacy effect in first impressions (Asch, 1952). The information presented first was found to be more influential in shaping the total impression of a stimulus person than the material presented later. In commenting upon these findings, Hovland notes that most of Luchins' *S*s failed to see any incompatibility between the earlier and later information, and he suggests that a primacy effect is most likely to occur under these conditions (Hovland, 1958,

pp. 144–146). Using the present terminology, we would say that Asch's primacy effect refers to the assimilation of the later material into the first presented category. When people recognize the incompatibility between the earlier and later information, they place the sets of information in separate categories relatively far apart psychologically, thus making assimilation unlikely.

SELF- AND OTHER-EVALUATIONS IN PSYCHOANALYTIC PROJECTION AND PARANOIA

There is no necessary reason, as far as the writer can see, why the social analogues of contrast and assimilation should be limited to opinion statements or even isolated judgments of other people. Conceivably, self-other relationships also should be subject to these effects. Furthermore, I would like to propose that part of the phenomenon usually referred to as projection can be understood as a contrast effect in the judgment of others relative to one's self.

In his famous study of projection, Sears (1936) defines this process in these terms: "A wish, attitude, or habit hierarchy which is not compatible with other attitudes or habits of an individual may be attributed by that individual to other persons rather than to himself providing he lacks insight into the fact that he himself possesses the trait in question" (p. 151). College men in three fraternities were asked to rate their fraternity brothers and themselves on four bipolar traits (e.g., stingy–generous). Two effects were noted. First, consistent with psychoanalytic theory, *S*s who lacked insight into the amount of a given trait they themselves possessed (i.e., whose self-ratings disagreed with the group consensus on them) attributed more of this trait to others than did the insightful *S*s. By the way, and as psychoanalytic theory does *not* suggest, this occurred whether the trait was socially desirable or not. Thus, a generous person who supposedly did not realize he actually was generous tended to attribute more generosity to his fraternity brothers than an equally generous person who knew he possessed this trait. The second effect was limited by Sears to the insightful *S*s. These people exhibited "contract-formation." For example, the more generous the individual knew he was the more he tended to see the others as stingy.

Sears seems to have regarded these as two distinct processes because he was concerned with the individual's insight into his *actual possession* of a trait. However, if our focus of attention is shifted to the *S*s' *self*-descriptions we can see there is only one effect here: judgmental contrast. In this case we have to assume that an individual's self concept (his category, "me") serves as his judgmental standard and that he perceives most of the others in his group as being somewhat different from him. "Projection" then becomes "contrast-formation." The actually generous person who perceives himself as stingy judges his fellow group members in reference to this self-anchorage, stingy, and the resulting contrast gives rise to the evaluation, generous. From this viewpoint, the important feature in the supposedly insightful *S*s is that they also utilize their self concept as the judgmental standard. As far as their evaluations of others is concerned, how these others see them is largely irrelevant (except perhaps in that the self-anchorage might be affected by knowing the opinions of others). Here too, the person judges others in reference to his image of himself, and contrast results to the extent that there is some perceived difference between the anchorage cat-

egory, self, and evaluated category, others.

More recently, Goldings (1954) has reported a study whose findings can readily be reconciled with the Sears' results. Judges were asked to rate their own degree of happiness and also to evaluate the happiness or unhappiness of people shown in a series of 30 pictures. Among other things, Goldings concluded: "At the extremes of happiness and unhappiness, *contrast projection* occurs: those who avow extreme happiness tend to attribute unhappiness to others and those who avow extreme unhappiness tend to attribute happiness to others. In more moderate degrees of happiness and unhappiness, regular supplementary projection occurs" (p. 42), i.e., the *S*s attributed their own feelings to the pictured individuals.

Although Goldings explicitly states that Sears' concepts cannot account for his findings (pp. 44–45), it seems to me that the two studies are easily brought together. To explain the later results we first have to assume that the pictured individuals on the average are located towards the middle of the happiness–unhappiness continuum. The judges who anchor themselves at the extremes of this continuum then perceive relatively great dissimilarity between themselves and the stimulus objects, and there is a contrast effect. On the other hand, for the judges whose self-standard is moderate happiness or moderate unhappiness, the distance between this anchorage and the evaluated category, others, is relatively small. The result is assimilation, or what Goldings, following H. A. Murray, terms supplementary projection.

In both experiments, therefore, the nature of the projection exhibited depends upon the psychological distance between the self-standard and the category of others being evaluated. If this distance is relatively great (as was the case for some of Goldings' *S*s and, presumably, most of Sears') we find contrast in the judgment of the others. However, when the distance is small (again, as was the case for some of Goldings' *S*s but few, if any, of those utilized by Sears) there is assimilation, or supplementary projection, in the judgment of others. Clearly, Sears' results parallel the previously cited findings obtained by Hovland and Sherif (1952) regarding the evaluations of opinion statements as a function of the judges' own strong attitudes on these issues, while the Goldings results essentially are close to the findings mentioned earlier in the study by Hovland, Harvey, and Sherif (1957).

This is not to say that psychoanalytic projection is entirely accounted for by the present judgmental phenomena; evaluation of others is only part of the process of projection. As Sears has pointed out, the psychoanalytic concept also involves lack of insight into (or the repression of knowledge of) the possession of undesirable traits, wishes, or ideas. His data suggest, furthermore, that these "undesirable" responses need not always be socially "bad." Some of his *S*s apparently did not realize they had "good" attributes such as generosity. If this lack of awareness is motivated, it may be, as Rogers has proposed (1951, Ch. 11), that the repression stems from a perceived inconsistency between the given trait and the individual's self concept.[3] At any rate,

[3] Rogers here has anticipated recent theoretical developments in social psychology, such as the Osgood and Tannenbaum (1955) incongruity hypotheses and Festinger's (1957) dissonance theory. In terms of this latter view, for example, knowledge of the possession of a trait incompatible with beliefs regarding the nature of the self is likely to produce psychologically uncomfortable "cognitive dissonance." Since the individual is motivated to reduce dissonance, he may repress (exclude from awareness)

regardless of the nature of repression, there is an additional component to this process that also must be considered: reaction formation. Frequently, when a person projects his own characteristics onto others, he not only lacks awareness that he has these characteristics, he leans over backward in denying them and insists to himself and others that he is just the opposite. All this can be illustrated by taking the case of the person most likely to exhibit projection, the paranoid.[4] According to psychoanalytic theory, the paranoid's basic problem involves latent homosexuality (Freud, 1925; Zamansky, 1958). This characteristic is threatening to him, he represses the drive, and projects it onto important others. However, even the attribution of homosexual desires to another supposedly provokes anxiety, so the idea is transformed from "he loves me" to "he hates me."

I would like to offer tentatively a somewhat different explanation for the dynamics of paranoia. As in analytic theory, the process commences when the individual judges himself (his "real" self) as being located towards the homosexual end of the heterosexual-homosexual continuum, while his ideals ("ideal" self) are anchored towards the extreme opposite end. The ideal self then serves as the standard by which others as well as the real self are evaluated. Several things then happen. First, the relatively great gap between the ideal and real selves upsets the individual, and in defense he (*a*) represses knowledge of his real self-evaluation, as well as (*b*) strongly insists, to himself and others, that he really is the way he would like to be. In this latter process he has not only repressed his homosexual attributes, he has exhibited reaction formation in characterizing himself as extremely nonhomosexual. At the conscious level his ideals and his self-image both are strongly heterosexual,[5] and it is from this extreme viewpoint that he judges others. The consequence, of course, is a contrast effect; other people are evaluated as more homosexual than they actually are. (But only people important to him are so evaluated because he does not bother to judge everyone he encounters.)

However, this judgment of others also may be threatening. The very idea, homosexuality, may arouse anxiety, and subsequent avoidance responses, so that even the characterization of another as possessing this disapproved motive is repressed. The emotion aroused by the initial judgment remains; the person is hated for possessing the evil trait, but the basis for the hatred is kept from awareness. Festinger (1957, pp. 235–243) has suggested that this state of affairs, strong emotion without a conscious explanation for it, is upsetting (produces dissonance) and motivates the individual to invent reasons for his feelings. (According to Festinger [cf. his citation on p. 235], Freud had recognized this phenomenon, but he nevertheless goes on to provide additional support for his thesis.) Following this lead, we would propose that to a considerable extent, the paranoid's ideas of being persecuted are the reasons he invents to give conscious meaning to his hatred for others.

Undoubtedly also contributing to this persecution complex are the paranoid's

knowledge of his possession of the incompatible trait.

[4] The ideas given in this section were stimulated to a considerable extent by discussions with Norman S. Greenfield.

[5] Extrapolating some of Festinger's observations (1957), we might say that the greater the uncertainty felt by the individual that he really is the way he thinks he is (i.e., the greater the dissonance regarding his conscious beliefs about himself)—up to some maximum level of doubt—the more strongly he will consciously deny these doubts and insist that the self-belief is correct.

assimilative tendencies. As will be discussed more fully later, the discrepancy between his ideals and his unverbalized self-image probably produces an extremely unfavorable self-evaluation. Since the basis for this evaluation is not known, it is easy for him to attribute this evaluation to others. In essence, he unconsciously dislikes himself and, as a result, consciously expects others also to dislike him. To employ the Postman-Bruner terminology of the early 1950's, he has an hypothesis of reproof, dislike, and even aggression from others. As a consequence, ambiguous events or acts that are not too obviously at variance from this hypothesis are assimilated into it. The paranoid expects this behavior from others and interprets appropriate stimulus situations in a manner consistent with his hypothesis. Postman and Brown (1952) have obtained evidence that is of some relevance here. They have shown that threat-associated stimuli are perceived readily by *S*s trained to have a failure self-hypothesis. Thus, not only would the paranoid assimilate ambiguous situations into his threat hypothesis; his threshold for the recognition of these threats also would be low.

Psychoanalytic theory obviously has contributed a great deal to this interpretation of paranoia. The major difference is that the present scheme weights the judgmental process much more heavily, particularly with regard to projection. According to this view, projection is not a defense in the usual meaning of this term, but rather, is a consequence of the evaluation of others. When the paranoid attributes disapproved traits to another he does so because there is a relatively great distance, psychologically, between the anchorage, his ideals and conscious self-characterization, and the indeterminate location of the other on the trait continuum.

Much of this analysis admittedly is speculation, but there are a number of implications here that seem to be consistent with quantitative evidence. It has been reported, for example, that judges tend to assume their friends are more like themselves than are persons they dislike (Fiedler, Warrington, & Blaisdell, 1952; Lundy, et al., 1955). Thus, a paranoid might tend to view others as being dissimilar to himself, increasing the psychological distance between these others and himself, not only because of his reaction formation-produced extreme self-evaluation, but also because of his dislike for the others. The result is that contrast projection becomes more likely, and additional fuel is thrown on the fire of hatred.

Fensterheim and Tresselt (1953) report some data that are pertinent here. They found that college students tended to attribute their *least* preferred values to strangers, and that this tendency was strongest for those strangers who were least liked. Since most of the *S*s saw themselves as possessing the values they preferred, it may well be that this preferred self-image served as the anchorage in the judgmental process. The results of this study then suggest: (*a*) that strangers often are regarded as fairly distant psychologically from the self, giving rise to a contrast effect ("they are different from me") and (*b*), as was proposed above, that feelings of unfriendliness toward the evaluated object serve to increase this distance, further heightening the contrast. Extrapolating from the Fensterheim-Tresselt findings, we can readily predict that the paranoid, hating other people, would be all too prone to attribute his least preferred characteristics to them. In his case this would appear to the psychoanalytically biased observer as projection.

The present analysis also proposes that there is a considerable discrepancy

between the paranoid's ideals (the way he would like to be) and his unverbalized image of his actual characteristics (his perceived real self). Rogers and his colleagues have shown (Butler & Haigh, 1954) that this ideal self-real self discrepancy frequently is found in people with personality disorders. It is easy to see why this discrepancy would have harmful effects: to the extent that the ideal self is utilized as the standard category, the contrast effect produced by a relatively great discrepancy between this and the real self results in the latter being evaluated even more unfavorably.

There is support for this prediction in a recent exploratory study conducted by the writer. Half of 52 *S*s in two psychology classes were asked to describe themselves on an adjective check list as they believed they "really were." The remaining *S*s performed this self-description task after first describing their ideals (what they wished they were like) on this check list. The saliency of the ideal self was thereby increased in this latter condition, and presumably, it therefore was more likely to have served as an anchorage affecting the subsequent judgments of the real self. The nature of this effect, of course, depends upon the distance between the ideal self anchorage and the evaluated object, the real self, and we assumed this distance would be greater the more dissatisfied the *S*s were with themselves. Each of the adjectives in the check list had been classified earlier as either "good" or "bad" (based upon the evaluations of a pool of judges), making it possible to score the favorableness of each *S*'s ideal self and real self descriptions. In addition, the *S*s in both conditions indicated on a graphic rating scale how satisfied they were with themselves. These latter self-satisfaction ratings supported the assumption regarding the discrepancy between ideal and real selves; for the *S*s who described their ideals, the greater the rated dissatisfaction with the self the greater the discrepancy in the favorableness of the ideal and real self descriptions. Each of the two experimental conditions was then dichotomized at the condition median on the self-satisfaction ratings, and the number of favorable adjectives attributed to the real self [6] on the check list was computed in each of the four resulting conditions. As expected, when their ideals had been made more salient, the *S*s who were relatively satisfied with themselves (and, it will be remembered, whose real selves were close to their ideals) evaluated their real selves significantly more favorably than the *S*s in any other condition. Similarly, the dissatisfied *S*s (whose real selves were far from their ideals) described themselves most unfavorably of all four groups of *S*s when put in the condition enhancing the likelihood of their ideals serving as a judgmental anchorage. Apparently, when our *S*s became more aware of their ideals, the subsequent evaluations of their real selves was affected. Those whose real selves were close to their ideals seemed to show assimilation, i.e., the favorableness of the real self-evaluation presumably was increased bringing it closer to the ideal self. On the other hand, the people whose real selves were relatively far from their ideals manifested a contrast-like effect; they evaluated themselves more unfavorably.[7]

[6] In actuality, the dependent variable was the number of favorable adjectives attributed to the real self *plus* the number of unfavorable adjectives that were said to be not characteristic of the person.

[7] These results do not seem to be due to a situation-induced correlation between the self-satisfaction ratings and ideal self-real self discrepancy in the case of the subjects describing their ideals, and the absence of such a correlation in the other condition. The *S*s in the former condition were much more likely to be at both extremes of the

It makes sense, therefore, to regard one of the principle aims of psychotherapy, at least in some instances, as the reduction of the ideal self-real self discrepancy, and Butler and Haigh (1954) and Rudikoff report (1954) such a discrepancy reduction in their investigation of psychotherapeutic results. Evaluating himself with an unrealistic set of ideals (Freud's harsh "superego") as the standard, the individual who sees himself as not living up to these ideals also is likely to judge himself, by contrast, as more of a failure than he actually is (e.g., as might be determined by an independent observer).

Of course, one of the major difficulties here, at least as far as research is concerned, is the frequent inaccessibility of the individual's unfavorable self-image to verbal report. That is, these unfavorable self-attitudes often are repressed. For example, we already have proposed that the paranoid is not consciously aware of his negative self-evaluation but instead describes himself in a highly positive manner. The previously cited investigations by Rogers and his colleagues, on the other hand, clearly imply that many neurotics are aware of their unfavorable self-portrayal. There is evidence supporting this interpretation in a paper published by Friedman (1955). Normal, psychoneurotic and paranoid schizophrenic subjects described themselves and their ideals utilizing the Q sort. For the paranoids the discrepancy between the real and ideal self was only slightly less than that for the normals (the statistically significant median r's were .42 and .62 respectively), but there was no relationship between these self-concepts in the case of the neurotics (median $r = .03$). Friedman concludes:

> . . . normals tend to see themselves as they would like to be, reflecting positive attitudes toward the self. The psychoneurotic group tended to regard their self qualities as being very much different from the way they would like to be . . . (but the positive self concept) of the paranoid schizophrenic group is based upon unrealistic self appraisal (p. 613).

This study also contains data consistent with other aspects of our analysis of paranoia. According to the present scheme, the paranoid is relatively unlikely to exhibit judgmental assimilation of others to his perceived positive values because his hostility towards others as well as his reaction formation, increases the psychological distance between himself (the standard category) and these others. Thus, he does not attribute his perceived self characteristics (as he consciously believes he is) to other people. Friedman's findings indicate that this is indeed the case. Both the normal and psychoneurotic groups tended to attribute their consciously perceived characteristics to the figures depicted in TAT cards (apparently in this case there wasn't the alienation or strangeness felt by the Fensterheim-Tresselt *S*s), but the paranoids did not.

Individual Differences in Categorizing Tendencies, the Authoritarian Personality, and Hostility Displacement

Up to this point we have seen that a variety of judgmental situations give rise to contrast or assimilation effects depending upon the distance between the standard category and the evaluated object or issue. This distance, in many cases, obviously can be determined objectively prior to the evalua-

favorableness of real self description continuum, while the remaining subjects tended to be in the middle of this continuum. In other words, the variance was greater in the former condition, as if the *S*s had been made to move out toward the extremes. However, in the absence of proof that their self-judgments had indeed changed, this conclusion must be tentative.

tion task. In other instances, however, it appears that this determination may be made more difficult by the characteristic categorizing behavior of the *S*s involved in the task. For example, the distance between the standard and the evaluated stimulus can be coordinated to the number of discrete categories the person can establish between them. Defining a category, with Bruner (1957), "as a set of specifications regarding what (stimuli) will be grouped as equivalent" (p. 133), *S*s who typically have broad equivalence ranges (i.e., utilize broad categories) are likely to perceive the anchor and the evaluated stimulus as more similar than *S*s who customarily establish narrow categories. Gardner (1953) and Pettigrew (1958) have shown that there are reliable individual differences in category width. In the former experiment people who established relatively small categories in an object-sorting test were less subject to brightness, size and shape constancy effects than people who adopted relatively large categories in this test. The former apparently made finer discriminations in their sensory judgments. Although Gardner did not test this possibility, we also would expect the people who typically set up narrow categories in their object sorting to be less likely than others to demonstrate judgmental assimilation and be quicker to manifest judgmental contrast with an objectively defined increasing distance between the anchor and the evaluated stimulus.

To complicate matters still further, individual differences in these judgmental effects may become evident in some evaluation situations but not in others. This is indicated in the research on the relationship between personality rigidity and problem solving. If a person were to go about solving all the problems given him in the same manner, even though the experimenter knows many types of solutions were available, conceivably, for this individual, the problems are equivalent. They are placed in the same category of problems and the same responses are made to them. In this sense, then, rigidity is a function of the breadth of an individual's categories. Roger Brown (1953) has demonstrated that highly authoritarian individuals (as defined by the California F scale) tend to exhibit greater problem-solving rigidity than less authoritarian subjects, but only when placed in a mildly stressful, ego involving situation. Translating this finding, we might say the authoritarian's categorizations generally become broader under mild stress. To put it another way, he does not make fine discriminations among the stimulus tasks confronting him in this type of situation.

Recently, the present writer has observed that some instances of hostility displacement may stem from an essentially similar process. An experiment was carried out to test the hypothesis that characteristically prejudiced people are more likely to displace frustration-instigated aggression upon an innocent bystander than are less prejudiced people. High and low anti-Semitic female college students were selected on the basis of their scores on a prejudice-assessing questionnaire, with half of each group later exposed to harsh and frustrating individual treatment by the experimenter. After this each *S* was required to work for a brief period with a peer (the experimenter's confederate) and then rate her degree of liking for the peer. For the nonangered *S*s, there was no difference between the high and low anti-Semitic girls in their rated friendliness toward the other girl. However, in comparison to these neutral-situa-

TABLE 1

MEAN EVALUATIONS OF THE FOUR NEUTRAL TRAITS FOLLOWING THE SEVEN ANCHORING TRAITS

	High F Scale Score		Low F Scale Score	
	Ego-involved	Nonego-involved	Ego-involved	Nonego-involved
Anchorage:				
"Good"	6.68_{bc}	7.45_{a}	7.10_{ab}	6.15_{cd}
"Bad"	6.12_{cd}	6.02_{de}	5.42_{e}	6.72_{bc}

Note.—(High Score = "Unfavorable" Evaluation; N = 10 in each condition).
Cells containing the same subscript are not significantly different from each other at the .05 level by Duncan multiple-range test.

tion ratings, the angered less prejudiced girls became friendlier toward the peer, while the angered more highly prejudiced subjects tended to become more hostile (Berkowitz, 1959).

If we assume that the *S*'s experience with the anger-arousing experimenter served as a judgmental anchorage, the reaction of the less prejudiced (less authoritarian) girls become a contrast effect: in contrast to the annoying experimenter, the peer seemed to be friendly and was so evaluated. On the other hand, if the stress of the frustrating situation served to broaden the highly prejudiced (more authoritarian) girls' categories, their hostility displacement is due to assimilation: the annoying experimenter and the peer were grouped together in the same category so that the hostility aroused by the former was generalized readily to the latter.

A judgment experiment conducted by the writer and Pauline Schoenberg tested this interpretation. As in Schilling's study, described above, the students were asked to judge the "goodness" of eleven personality traits, with the first seven traits, all clearly "good" or all clearly "bad," providing the anchorage, and the remaining four being relatively neutral. Schilling's investigation had shown, it will be recalled, that contrast is relatively unlikely to occur when the traits all refer to the same individual. These instructions were utilized throughout in the present experiment; the *S*s were told the adjectives described traits possessed by one person, Joe, and each trait was introduced by the phrase, "Joe is ——."

Eight conditions were created in a factorial design for the study. Half of the *S*s, taken from a pool of previously tested volunteers, came from the upper third of the distribution of F scale scores, with the remaining *S*s coming from the lowest third. Half of each of these groups then was made to be ego involved in the experiment by telling the *S*s their judgments were a test of them, while the other *S*s presumably were less ego involved. Finally, within each of these resulting four conditions, half of the *S*s had the "good" anchorage and the others the "bad" anchorage.

The mean judgments of the neutral traits in each condition are shown in Table 1. Beginning at the right with the nonego involved low authoritarian *S*s, it can be seen that the neutral traits were judged on the whole somewhat (but not significantly) more favorably when preceded by the "good" rather than the "bad" anchorage. In other words, there is an indication here of an assimilation effect. Moving on to the next column, the mildly stressful ego-involving instruction served to eliminate this judgmental tendency in the less authoritarian *S*s and there is a significant contrast effect. Presumably, the stress tended to narrow the categories established by these people resulting in a sharp differentiation between the seven anchoring stimuli and the four more neutral traits. This finding seems to parallel the results obtained for the angered less

prejudiced girls in the hostility-displacement study. As mentioned earlier, these girls under stress also had tended to sharpen their differentiation between the frustrating experimenter and their neutral peer co-worker.

This discrimination apparently is the "normal" state of affairs for the highly authoritarian *S*s. As shown in the table, these *S*s differentiated the anchoring stimuli from the more neutral traits and displayed a significant contrast effect. However, as predicted mild stress apparently weakened this judgmental tendency somewhat. Table 1 indicates there was a reliable decrease in the contrast effect manifested in the evaluations of the neutral stimuli following the "good" anchorage. It may be, as we have hypothesized, that the conceptual categories set up by the authoritarian tend to broaden under stress, thereby reducing the psychological distance between the standard and the evaluated stimuli [8] and, as a consequence, weaking the judgmental contrast. If so, this broadening can account for at least some of the hostility displacement shown by the angered highly prejudiced girls. In this case stress caused them not to differentiate the frustrator from the available bystander so that the aggression aroused by the former generalized to the latter.

[8] Note that the highly authoritarian *S*s under stress still tended to rate the neutral traits somewhat more unfavorably after the "good" anchorage than after the "bad" anchorage. This moderate contrast effect indicates they still were not acting in conformity to the instruction that the traits all referred to one individual, so that the decrease in the magnitude of this contrast probably was not due to a stress-induced adherence to the instructions. Furthermore, since the instruction on this point was very explicit and each trait was introduced by a phrase reminding the *S* of the single-person referent, there is little doubt that the *S*s in every condition were aware of the instruction. Similarly, the lower evaluation scores in this condition probably were not caused by an increase in rating conservatism (an increased desire to "play it safe" in their evaluations by avoiding extremely "good" ratings). The authoritarian *S*s under the mild stress rated the anchoring traits in as extreme a manner as the other groups of *S*s. On the other hand, if they had decided "safety" lay in being consistent in their evaluations, they would have shown a much stronger "assimilation" effect than actually occurred.

SUMMARY

Assuming the underlying unity of psychology, the present paper has attempted to show that judgmental principles uncovered in the psychophysics laboratory and recently extended to social evaluation situations can also be applied to personality functioning. These principles deal with judgmental contrast and assimilation, and it is proposed, for example, that psychoanalytic projection is readily understood as a special instance of these phenomena.

The theme of the unity of psychological science also runs strongly through the tentative theory of paranoia presented here. From psychoanalytic theory, we assume that much of the paranoid's behavior stems from repressed homosexuality. However, our description of the reactions to this disapproved drive leans heavily on recent social psychological theorizing, particularly Festinger's theory of cognitive disonance. Whether the details of this analysis is correct or not is relatively unimportant. As far as the writer is concerned, it is much more important to demonstrate that the laboratory researcher does deal with material of relevance to the clinician and that this is true even when he studies judgments of lifted weights. Aberrant

At any rate, a more recent investigation completed after this paper had gone to press, employing the same procedures but without the "all-one-person" instruction, obtained essentially the same pattern of differences between the high and low authoritarian *S*s.

phenomena are not in a world entirely apart from the normal. In many respects they can profitably be regarded as special cases of more general psychological principles.

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